ALTER VERSUS ALTERSSIMULATION

Effekte von Alter und Alterssimulation auf kognitive und motorische Leistungen, Selbstwahrnehmung, Entscheidungsverhalten und motorisches Lernen

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Zusammenfassung

Altwerden geht mit einer Vielzahl biologischer Veränderungsprozesse und einer verminderten Leistungsfähigkeit in unterschiedlichen Domänen einher. So unterscheiden sich junge und ältere Erwachsene in ihren sensorischen, motorischen und kognitiven Fähigkeiten sowie in ihrer Selbstwahrnehmung, ihrem motorischen Entscheidungsverhalten und beim Erlernen von Bewegungen. Die Gründe für diese altersbedingten regressiven Veränderungen lassen sich stark vereinfacht ausgedrückt in zugrundeliegende Verschlechterungen bei peripheren Prozessen (z. B. Sensorik) und zentralen Mechanismen (z. B. Informationsverarbeitung) unterteilen. Veränderungen in der Körperperipherie sollen durch das Tragen von Alterssimulationsanzügen nachgeahmt werden können. Die Ganzkörperanzüge sollen die gängigsten körperlichen Einschränkungen des Alters, wie nachlassende Seh- und Hörkraft und beeinträchtigte Greif- und Gangbewegungen, simulieren. Sie ermöglichen demnach die Untersuchung von eher peripheren Faktoren im Verhältnis zu zentralen/kognitiven Faktoren. In dieser Dissertation wurde den Fragen nachgegangen, ob 1) das Tragen von einem Alterssimulationsanzug bei jungen Erwachsenen zu quantifizierbaren Leistungseinbußen in verschiedenen Domänen führt und 2) nachlassende kognitive Leistungen bei älteren Erwachsenen mit nachlassenden motorischen Lernleistungen korrelieren. In drei Experimenten wurde untersucht, inwiefern sich der Altersanzug auf die motorische und kognitive Leistung sowie die Selbstwahrnehmung (Beitrag 3), das motorische Entscheidungsverhalten in unterschiedlichen Aufgabenkontexten (Beitrag 2) und das motorische Sequenzlernen bei jungen Erwachsenen auswirkt (Beitrag 1). In Beitrag 4 wurde anhand einer einfachen Sequenzbewegung evaluiert, inwiefern kognitives und motorisches Altern zusammenhängen und welchen Einfluss die Ausführungsgeschwindigkeit auf die Lernleistung älterer Erwachsener hat. Die Ergebnisse der Beiträge 1 bis 3 zeigen, dass das Ausmaß der Leistungseinbußen in den unterschiedlichen Domänen maßgeblich von der durchzuführenden Aufgabe abhängt. In Beitrag 3 konnten starke Effekte des Anzuges auf die motorischen und kognitiven Leistungen sowie die Selbstwahrnehmung der jungen Erwachsenen gefunden werden. In Beitrag 2 zeigte sich, dass das Entscheidungsverhalten junger Erwachsener nicht nur durch den Anzug, sondern auch durch die Aufgabencharakteristik der motorischen Aufgaben beeinflusst wird. Beitrag 1 konnte keinen Effekt des Altersanzuges auf die motorische Lernleistung der jungen Erwachsenen zeigen. Gezeigt wurde jedoch, dass ein Teil der Varianz der motorischen Lerndefizite bei älteren Erwachsenen durch reduzierte kognitive Leistungen erklärt werden kann. Dies wird durch die Ergebnisse von Beitrag 4 gestützt, die verdeutlichen, dass es bei älteren Erwachsenen einen Zusammenhang zwischen der nachlassenden Informationsverarbeitungsgeschwindigkeit und Defiziten beim motorischen Sequenzlernen gibt. Der Befund ist unabhängig von der Ausführungsgeschwindigkeit.

Inhaltsverzeichnis

Abkürzungsverzeichnis

DS	Digit Symbol Substitution-Test
FS	Figural Speed-Test
GERT	Gerontologischer Testanzug
MoCA	Montreal Cognitive Assessment
mmtd	Maximal beherrschbare Aufgabenschwierigkeit
RMSE	Root Mean Square Error

1 Einleitung

Global wie national betrachtet werden Bevölkerungen immer älter. Die stetig steigende Zahl an älteren Erwachsenen führt auch zu einer Gesellschaft, die immer schneller altert. Dieser Prozess bringt in vielen Lebensbereichen Veränderungen mit sich, die positiv, aber auch mit Sorge betrachtet werden können. Der alternden Bevölkerung bieten sich Möglichkeiten, zum Beispiel durch die Benutzung neuer Technologien (wie Smartphones oder Tablets), aktiv an einer immer stärker digitalisierten Welt teilzuhaben. Gerade in Zeiten einer Pandemie zeigt sich, wie wichtig digitale Kommunikation (z. B. durch Videotelefonie) für die soziale Interaktion und Teilhabe sein kann. Die Möglichkeit der E-Mobilität, beispielsweise durch die Benutzung von E-Bikes, kann körperliche Betätigung erleichtern und somit auch zur Gesunderhaltung beitragen. Um die Angebote wahrzunehmen, müssen ältere Erwachsene die Bereitschaft mitbringen, sich neues Wissen anzueignen, bestehendes Verhalten und Handeln anzupassen, und neue Bewegungen erlernen zu wollen. Zugleich sind ältere Menschen mit großen Herausforderungen konfrontiert. So steigt mit zunehmendem Alter beispielsweise das Risiko für bestimmte Krankheiten (z. B. Diabetes, Herz-Kreislauferkrankungen, Arthritis oder Demenz, siehe Dumurgier & Tzourio, 2020; Kastner et al., 2018). Weiterhin können negative Erlebnisse, wie Schicksalsschläge oder Stürze, zu Ängsten und Vermeidungsverhalten führen. Zudem gehen altersbedingte biologische Veränderungsprozesse mit verminderten Fähigkeiten und Leistungen in verschiedenen Bereichen einher (siehe Übersichtsartikel von Kuehn et al., 2018). Verminderte Seh- und Hörleistungen, eine geringere Ausdauer und Beweglichkeit, sowie Schwierigkeiten, sich Dinge zu merken oder sich zu konzentrieren, sind alltägliche Probleme für ältere Erwachsene. Vor diesem Hintergrund ist ein gesundes und selbstbestimmtes Altern, bei dem kognitive und motorische Fähigkeiten möglichst lang erhalten bleiben sollen, umso bedeutsamer.

Die Frage nach den Ursachen der vielfältigen altersbedingten Leistungsveränderungen beschäftigt Wissenschaftler[1] unterschiedlicher Forschungsbereiche schon seit Jahrzehnten (z. B. S.-C. Li et al., 2004; Park, 2000; Willimczik et al., 2006). Diese Arbeit soll mögliche Gründe für die kognitiven und motorischen Leistungsunterschiede und Unterschiede im motorischen Lernen sowie Unterschiede in der Selbstwahrnehmung und im motorischen Entscheidungsverhalten zwischen jungen und älteren Erwachsenen aufzeigen. Der Schwerpunkt der Arbeit liegt auf den körperlichen Veränderungen im Altersgang und ihren Effekten auf die zuvor genannten Bereiche. In diesem Zusammenhang soll der Frage nachgegangen werden, ob die

[1] Aus Gründen der besseren Lesbarkeit wird im Folgenden auf die gleichzeitige Verwendung weiblicher und männlicher Sprachformen verzichtet und das generische Maskulinum verwendet. Sämtliche Personenbezeichnungen gelten gleichermaßen für beide Geschlechter.

körperlichen Einschränkungen des Alters bei jungen Menschen durch das Tragen eines Altersanzuges simuliert werden können.

Durch Alterssimulationsanzüge sollen die gängigsten körperlichen Einschränkungen des Alters, wie nachlassende Seh- und Hörkraft oder beeinträchtigte Greif- und Gangbewegungen, nachgeahmt werden (Meyer-Hentschel, 2021; MIT AgeLab, 2019; Moll, 2021). Sie bieten dem Träger die Möglichkeit, Eindrücke über körperliche Einschränkungen älterer Menschen zu gewinnen, und schärfen so auch seine Wahrnehmung für Alltagsschwierigkeiten von Senioren. Das Erfahrbarmachen der Auswirkungen des sensorischen und motorischen Abbaus durch das Anzugtragen birgt die Chance, vor allem bei jüngeren Menschen das Verständnis für ältere Mitmenschen zu erhöhen. Verschiedene Studien haben gezeigt, dass das Anzugtragen die Empathie junger Menschen für ältere Erwachsene steigern kann (Green & Dorr, 2016; Tullo et al., 2010). Das Anliegen dieser Arbeit ist es jedoch, herauszufinden, ob das Tragen des Altersanzuges zu quantifizierbaren Ähnlichkeiten in den (Lern-)Leistungen oder dem Entscheidungsverhalten junger und älterer Erwachsener führt. Ähnliche Ergebnisse zwischen älteren und jungen Erwachsenen im Anzug würden hinsichtlich der (Lern-)Leistungen die Bedeutung altersbedingter peripherer Beeinträchtigungen hervorheben.

Im Sinne der *specific cause*-Hypothese (Christensen et al., 2001; Gilmore et al., 2006; Kiely & Anstey, 2015; B. A. Schneider et al., 2005; siehe Glass, 2007 für die *direct cause*-Hypothese) wäre dies ein Indiz dafür, dass bei älteren Erwachsenen unabhängige, domainspezifische Faktoren die motorischen und kognitiven Leistungen sowie das motorische Lernen entscheidend mitprägen. Je nach Aufgabe können beispielsweise die nachlassende Sensorik (z. B. der Augen oder Ohren), die schwindende Muskelkraft (z. B. der Arme oder Beine) oder Koordinationsschwierigkeiten, einzeln oder im Verbund wirkend, die reduzierten motorischen (Lern-)Leistungen von älteren Menschen erklären. Ein weiterer Ansatz, nämlich der der *common cause*-Hypothese (Ghisletta & Lindenberger, 2005; Lindenberger & Baltes, 1994, 1997; Lindenberger & Ghisletta, 2009), sieht den Rückgang von kognitiven, sensorischen und sensomotorischen Funktionen in einem allgemeinen Mechanismus begründet. Die altersbedingten biologischen Veränderungen des Gehirns werden als Generalfaktor angesehen und führen zu vielfältigen Beeinträchtigungen der Informationsverarbeitung. Diese wirken sich leistungsübergreifend aus, wodurch mit fortschreitendem Alter ein zunehmender Zusammenhang zwischen kognitiven, sensorischen und sensomotorischen Funktionen entsteht. In Bezug auf die motorischen und kognitiven Leistungseinbußen soll der Einsatz von Alterssimulationsanzügen zur Debatte über allgemeine oder spezifische Ursachen für die Verschlechterung im Alter beitragen. In diesem Kontext soll vor allem Beitrag 3 (Vieweg & Schaefer, 2020) neue Erkenntnisse beisteuern. Neben den motorischen und kognitiven Leistungen wurde in Beitrag 3 auch die veränderte Selbstwahrnehmung junger Erwachsener untersucht. Es wurde erforscht, inwiefern sich der akute Zustand des Anzugtragens bei jungen Erwachsenen auf die Wahrnehmung ihrer Körperverfassung und ihrer Stimmung auswirkt.

Auch die altersbedingten Beeinträchtigungen beim motorischen Lernen, zum Beispiel in Form von langsameren und variableren Bewegungsausführungen älterer Menschen, werden vor dem Hintergrund der Bedeutung peripherer und zentraler Prozesse diskutiert (Bo et al., 2009; Cai et al., 2014; Chaput & Proteau, 1996; Voelcker-Rehage, 2008). Einigkeit herrscht darüber, dass altersbedingte Abnahmen der sensomotorischen Kontrolle nicht als einheitliches Defizit betrachtet werden können, sondern sich vielmehr in spezifischen Defiziten (wie Schwierigkeiten bei der Verarbeitung von Reizen oder Probleme mit der Regulierung der Bewegungsgeschwindigkeit), äußern können (Seidler & Stelmach, 1995). So sollte bei älteren Erwachsenen der Einfluss zentraler Gedächtnis- und Verarbeitungsprozesse beim Lernen einer einfachen motorischen Bewegungssequenz untersucht werden. In Beitrag 1 (Vieweg et al., 2022) wurde nicht nur untersucht, wie bei älteren Erwachsenen die (perzeptuelle) Verarbeitungsgeschwindigkeit mit ihrer Leistung im motorischen Sequenzlernen kovariiert, sondern auch, ob das Tragen eines Altersanzuges bei jungen Menschen zu ähnlichen Leistungen wie bei älteren Probanden führt. So können einerseits die Leistungsunterschiede zwischen jungen Erwachsenen im Anzug und älteren Erwachsenen im Hinblick auf die specific cause-Hypothese untersucht werden. Andererseits ermöglicht die Korrelation zwischen der Geschwindigkeit von Informationsverarbeitungsprozessen und der motorischen Lernleistung Einblicke in den Zusammenhang zwischen kognitivem und motorischem Altern. Die gemeinsame Verflechtung von degenerativen kognitiven und sensomotorischen Prozessen im Alter könnte als Indiz für die common cause-Hypothese gewertet werden. Mit Beitrag 4 (Vieweg et al., 2020) sollte neben der Bedeutung des Zusammenhangs von kognitivem und motorischem Altern auch der Frage nachgegangen werden, wie sich eine verlängerte Bewegungszeit (und somit langsamere Bewegungsausführung) bei älteren Erwachsenen auf das Lernen einer einfachen Sequenzbewegung auswirkt. Angesichts der Schwierigkeit älterer Menschen, Elemente einer Bewegungssequenz zu organisieren und die entsprechenden Bewegungskommandos zu planen und auszuführen (z. B. Shea et al., 2019; Verwey, 2010), könnte eine langsamere Bewegungsausführung diese Prozesse vereinfachen. Hierfür lernten junge und ältere Probanden eine einfache Sequenzbewegung unter zwei verschiedenen Ausführungsgeschwindigkeiten (1300 und 2000 ms).

Die Frage nach der Aufgabencharakteristik spielt nicht nur hinsichtlich der motorischen (Lern-)Leistungsunterschiede zwischen Jung und Alt eine bedeutsame Rolle, sondern auch im Hinblick auf das Entscheidungsverhalten älterer Menschen. Studienergebnisse zur Selbsteinschätzung älterer Erwachsener bei kognitiven und motorischen Aufgaben zeigen, dass sie dazu neigen, sich in ihren Fähigkeiten zu überschätzen (Butler et al., 2015; Crawford & Stankov, 1996; Hansson et al., 2008; Sakurai et al., 2013, 2014, 2017). Andererseits weisen

Ergebnisse aus der Doppelaufgaben-Forschung darauf hin, dass ältere Erwachsene bei körperlich anspruchsvollen und fordernden motorischen Aufgaben dazu neigen, diese bei der Ausführung zu präferieren (K. Z. H. Li et al., 2001; Lövdén et al., 2005; Lundin-Olsson et al., 1997; Schaefer, 2014; Woollacott & Shumway-Cook, 2002). In Beitrag 2 (Schaefer et al., 2022) wurde deshalb untersucht, wie sich das Entscheidungsverhalten zwischen jungen und älteren Erwachsenen in zwei verschiedenen motorischen Aufgaben unterscheidet. Die gewählten motorischen Aufgaben (Tragen eines Tabletts und Übersteigen eines Hindernisses) wurden hinsichtlich ihrer Ausführung als unterschiedlich körperlich fordernd bzw. anspruchsvoll eingestuft. Die Probanden konnten den Schwierigkeitsgrad der durchzuführenden Aufgabe selbstständig bestimmen. Weiterhin sollte untersucht werden, inwiefern sich das Tragen eines Altersanzuges auf das motorische Entscheidungsverhalten der jungen Erwachsenen auswirkt.

2 Überblick: Publikationen

In diesem Kapitel werden die einzelnen Beiträge, die Bestandteil der kumulativen Dissertation sind, aufgelistet und die eigenen Arbeitsanteile an dem jeweiligen Beitrag beschrieben (Tabelle 1). Die Beiträge sind in Tabelle 1 nach Publikationsdatum geordnet (absteigende Aktualität). Alle Beiträge sind in englischer Sprache verfasst und in internationalen wissenschaftlichen Zeitschriften mit *Peer-Review* Verfahren eingereicht worden. Drei der Beiträge sind publiziert und Beitrag 1 befindet sich derzeit in der Einreichungsphase. Alle Beiträge stellen empirische Untersuchungen dar, die überwiegend im Arbeitsbereich „Bewegungswissenschaft, Motorik und Kognition“ (Leitung Prof. Sabine Schäfer) und auch im Arbeitsbereich „Trainingswissenschaft“ (Leitung Prof. Stefan Panzer) durchgeführt worden sind. Die Originalbeiträge sind im Anhang der Synopse beigefügt.

Tabelle 1

Auflistung und Arbeitsanteile der Autorin an den eingereichten Beiträgen, die Teil der kumulativen Dissertation sind

Beitrag 1	Vieweg, J., Panzer, S., & Schaefer, S. (2022). Effects of age simulation and age on motor sequence learning: Interaction of age-related cognitive and motor decline. *Human Movement Science, 87,* 103025. Advance online publication. https://doi.org/10.1016/j.humov.2022.103025
	SP, SS und **JV** haben das Konzept und Design der Studie gemeinsam entwickelt. **JV** hat die Aufbereitung der Literatur vorgenommen und die Daten erhoben. **JV** hat die Daten analysiert und mit Unterstützung von SP und SS interpretiert. **JV** hat das Verfassen und Einreichen des Manuskripts geleitet, mit Beiträgen von SP und SS.
Beitrag 2	Schaefer, S., Bill, D., Hoor, M., & Vieweg, J. (2022). The influence of age and age simulation on task-difficulty choices in motor tasks. *Aging, Neuropsychology, and Cognition*, 1–26. https://doi.org/10.1080/13825585.2022.2043232
	SS hat das Konzept der Studie entwickelt und gemeinsam mit DB, MH und **JV** das Studiendesign entworfen. Alle Autoren haben zur Literaturaufbereitung beigetragen. DB, MH und **JV** haben die Daten gemeinsam erhoben. SS hat die Daten analysiert und mit Unterstützung von DB und MH interpretiert. SS hat das Verfassen und Einreichen des Manuskripts geleitet, mit Beiträgen von **JV**.

Beitrag 3	Vieweg, J. & Schaefer, S. (2020). How an age simulation suit affects motor and cognitive performance and self-perception in younger adults. *Experimental Aging Research, 46*(4), 273-290. https://doi.org/10.1080/0361073X.2020.1766299
	JV und SS haben das Konzept und das Studiendesign gemeinsam entwickelt und beide zur Literaturaufbereitung beigetragen. **JV** hat die Daten erhoben. **JV** hat die Daten mit Unterstützung von SS analysiert und interpretiert. **JV** hat das Verfassen und Einreichen des Manuskripts geleitet, mit substanziellen Beiträgen von SS.
Beitrag 4	Vieweg, J., Leinen, P., Verwey, W. B., Shea, C. H., & Panzer, S. (2020). The cognitive status of older adults: Do reduced time constraints enhance sequence learning? *Journal of Motor Behavior, 52*(5), 558-569. https://doi.org/10.1080/00222895.2019.1654970
	SP hat das Konzept und das Design der Studie entwickelt. SP und **JV** haben beide zur Literaturaufbereitung beigetragen. **JV** hat die Daten erhoben. **JV** hat die Daten mit Unterstützung von SP analysiert und interpretiert. SP hat das Verfassen und Einreichen des Manuskripts geleitet, mit substanziellen Beiträgen von **JV**.

3 Forschungsschwerpunkte

In diesem Kapitel werden der aktuelle Forschungsstand und die zugrundeliegenden Theorien der Forschungsschwerpunkte vorgestellt und die eigenen Beiträge in diese eingebettet. In Kapitel 3.1 liegt der Schwerpunkt auf den degenerativen körperlichen Veränderungen, die mit dem Älterwerden einhergehen. Darüber hinaus wird untersucht, inwiefern sich diese auf motorische und kognitive Leistungen, aber auch auf die Selbstwahrnehmung und Selbsteinschätzung älterer Erwachsener auswirken. Gleichzeitig wird der Frage nachgegangen, ob die altersbedingten Veränderungen in der Körperperipherie und ihre Effekte auf die zuvor genannten Bereiche durch das Tragen von Alterssimulationsanzügen nachgeahmt werden können. Mit Blick auf das motorische Lernen werden in Kapitel 3.2 die Leistungsunterschiede zwischen jungen und älteren Erwachsenen genauer betrachtet. Neben der Bedeutung körperlicher Veränderungsprozesse wird auch das Zusammenspiel kognitiver und motorischer Leistungen bei Letzteren beschrieben. Der Fokus liegt hier auf der Interaktion nachlassender Verarbeitungsgeschwindigkeit zentraler Informationen und dem verminderten motorischen Lernen bei älteren Erwachsenen. Durch das Tragen eines Altersanzuges wird die Möglichkeit der Untersuchung eher peripherer Faktoren im Verhältnis zu zentralen/kognitiven Faktoren beim motorischen Sequenzlernen diskutiert.

3.1 Prozesse des Alterns und Alterssimulation

3.1.1 Körperliche Veränderungen und ihre Auswirkungen auf die Kognition, Motorik, Selbstwahrnehmung & Selbsteinschätzung

Das Altern wird typischerweise mit Veränderungen des Körpers, der Motorik und der Kognition assoziiert. Auch wenn Alterungsprozesse sehr heterogen verlaufen und durch viele unterschiedliche Faktoren beeinflusst sind (z. B. Bildung, Erziehung, aktiver Lebensstil, genetische Prädispositionen, Gesundheit), sind auf körperlicher Ebene vor allem degenerative Veränderungen zu konstatieren. Neben dem nachlassenden sensorischen Vermögen der Augen, Ohren und des Tastempfindens (Amaied et al., 2015; Campos et al., 2018; Roberts & Allen, 2016; Schieber et al., 2006), reduziert sich beispielsweise auch die Kraft, die Beweglichkeit, das Gleichgewicht und auch die Feinmotorik bei älteren Erwachsenen (Holland et al., 2002; Hunter et al., 2016; Leversen et al., 2012; Willimczik et al., 2006). Physiologische Faktoren auf neuromuskulärer Ebene zeigen sich zum Beispiel in Form der Sarkopenie, die den zunehmenden Abbau von Muskelkraft, Muskelmasse und Muskelfunktion mit fortschreitendem Alter beschreibt (Anker et al., 2016; Cruz-Jentoft et al., 2010). Hunter et al. (2016) begründen die nachlassenden motorischen Leistungen bei alten und sehr alten Erwachsenen (über 80 Jahre) mit deren Muskeln, die langsamer, weniger (maximal) kraftvoll und ermüdbarer bei der Ausführung dynamischer und sehr schneller Bewegungsaufgaben sind. Die Beeinträchtigungen der motorischen Leistung werden hier auf altersbedingte Veränderungen in der Morphologie und die Eigenschaften der motorischen Einheiten zurückgeführt (z. B. reduzierte und variablere synaptische Inputs, weniger und größere motorische Einheiten, weniger stabile neuromuskuläre Verbindungen und kleinere und langsamere Skelettmuskelfasern). Zugleich verweisen Hunter et al. auf die große Variabilität innerhalb und zwischen älteren Individuen bei vielen Aspekten der motorischen Leistung (z. B. Kraft, Geschwindigkeit, Ermüdbarkeit), die mit steigendem Alter noch weiter zunimmt.

Auch das Gehirn erfährt neurochemische, anatomische und funktionelle Veränderungen mit dem Altern. Neben der Volumenabnahme an grauer Substanz (z. B. im Frontallappen) und einer verminderten Integrität der weißen Substanz zeigen sich auch Verringerungen der Bindungspotentiale und Rezeptorendichte bei Neurotransmittern, wie dem Dopamin und Serotonin (als Review, siehe Grady, 2012). Unterschiede in der strukturellen und funktionellen Aktivierung kortikaler Regionen, die als aufgabenspezifisch gelten, werden als Gründe für die unterschiedlichen Verhaltensleistungen von Jung und Alt gesehen (Damoiseaux, 2017; S.-C. Li & Dinse, 2002). Über bildgebende Verfahren, zum Beispiel die funktionelle Magnetresonanztomographie, wird versucht, einen Zusammenhang zwischen neuronaler Aktivität (auf struktureller und funktioneller Ebene) und der Verhaltensebene herzustellen. Die Befundlage zum Ausmaß der Aktivierung aufgabenrelevanter Regionen bei jungen und älteren Erwachsenen ist sehr heterogen und zum Beispiel von der Schwierigkeit der Aufgabe, der Art der Verhaltens- beziehungsweise Leistungsmessung und dem Zeitpunkt im Übungs- beziehungsweise Lernverlauf abhängig. Dies kann zu verschiedenen Strategien und auch zu Wechseln in diesen führen (z. B. Kompensation oder Überrekrutierung; Grady, 2012). Neuere Befunde zeigen zudem, dass die Plastizität des Gehirns, also die Eigenschaft, veränderbar zu bleiben, bei älteren Personen weiter erhalten bleibt (Brehmer et al., 2014; Cai et al., 2014; Pauwels et al., 2018). Dies zeigt sich darin, dass Synapsen, Nervenzellen oder ganze Hirnareale aufgaben- bzw. nutzungsabhängig in ihrer Anatomie und Funktion angesprochen werden können. Studien aus der Kognitionspsychologie zeigen, dass kognitive Funktionen, wie beispielsweise das Gedächtnis, die Aufmerksamkeit, das Denken und exekutive Funktionen (z. B. Arbeitsgedächtnis), altersbedingte Verschlechterungen erfahren (Diamond, 2013; S.-C. Li et al., 2004; S.-C. Li & Dinse, 2002; Park et al., 2001; Rönnlund et al., 2005; Verhaeghen & Salthouse, 1997). Neben den strukturellen und funktionellen Veränderungen der involvierten kortikalen Regionen liegen die Gründe auch in der Beeinträchtigung der zugrundeliegenden kognitiven Prozesse. Beispielsweise nehmen die Geschwindigkeit, aber auch die Menge an Informationen, die simultan verarbeitet werden können, mit steigendem Alter ab (Salthouse, 1996, 2000). Der Zusammenhang zwischen zentralen Verarbeitungsprozessen und kognitiven Fähigkeiten, wie die Robustheit der Verarbeitung und fluider Intelligenz, wird mit zunehmendem Alter stärker und trägt so zur Minderung kognitiver Leistungen bei (S.-C. Li et al., 2004; Verhaeghen & Salthouse, 1997).

Das Zusammenspiel der vielfältigen strukturellen und funktionellen Veränderungen des menschlichen Körpers führt bei älteren Menschen zu Leistungseinbußen in verschiedenen Bereichen. Diese Leistungseinbußen zeigen sich sowohl für Aufgaben, die eher kognitive Anforderungen beinhalten, als auch für Aufgaben, die eher einen motorischen Schwerpunkt haben. Die degenerativen Veränderungen der kognitiven Funktionen und der (Senso-) Motorik sollten jedoch nicht losgelöst voneinander betrachtet werden. Vielmehr gibt es aus verschiedenen Forschungsrichtungen den Hinweis, dass Leistungseinbußen in der Motorik beispielsweise mit Veränderungen auf neuronaler Ebene einhergehen oder sich degenerative Prozesse der Sensomotorik und der Kognition gegenseitig bedingen (Cai et al., 2014). Hunter et al. (2016) führen zum Beispiel die größere Variabilität in der motorischen Leistung bei älteren Erwachsenen auf neuronale Ursprünge zurück, die in einer erhöhten Variabilität der willkürlichen Aktivierung und langsameren und variableren Entladungsraten der motorischen Einheiten liegen. Mit zunehmendem Alter ist nicht nur die sensomotorische Verarbeitung beeinträchtigt, sondern die kognitive Beteiligung an sensorischen und sensomotorischen Prozessen scheint auch zuzunehmen (Kiely & Anstey, 2015; K. Z. H. Li & Lindenberger, 2002 und S.-C. Li & Dinse, 2002). Gleichzeitig beeinflusst der Verlust an sensorischen und sensomotorischen Inputs die kognitive Leistungsfähigkeit. Nach der common cause-Theorie (gemeinsame Ursache), lässt sich die erhöhte Wechselbeziehung zwischen kognitiven und sensorischen Leistungen mit zunehmendem Alter durch eine gemeinsame Ursache erklären, nämlich die Alterung des Gehirns (Ghisletta & Lindenberger, 2005; Lindenberger & Baltes, 1994, 1997; Lindenberger & Ghisletta, 2009). Gleichzeitig gibt es aber auch die Annahme der specific cause (spezifische Ursache), die in der Verschlechterung domainspezifischer Faktoren einen direkten Einfluss auf kognitive Funktionen sieht (z. B. Christensen et al., 2001; Kiely & Anstey, 2015). Die altersbedingte Verschlechterung sensorischer Fähigkeiten, zum Beispiel der visuellen Kontrastempfindlichkeit, kann vor allem bei kognitiven Aufgaben mit hoher sensorischer Beanspruchung einen direkten Einfluss auf die kognitive Leistung haben (Glass, 2007).

Zusätzlich zu den körperlichen Veränderungen und den Interaktionen zwischen nachlassenden sensorischen, motorischen und kognitiven Prozessen spielen auch die gewählten Aufgaben und ihre Anforderungen eine entscheidende Rolle für die Selbstwahrnehmung und Selbsteinschätzung junger und älterer Erwachsener. Beide Gruppen treffen Entscheidungen mit Hilfe der Einschätzung ihrer eigenen Fähigkeiten. Generell wird davon ausgegangen, dass junge Erwachsene gut in der Lage sind, ihre eigenen Fähigkeiten einschätzen und somit auch angemessene Aufgabenschwierigkeiten auswählen zu können (Schaefer et al., 2021). Die Entscheidungsfindung kann auch von der Wahrnehmung des akuten körperlichen Zustands beeinflusst werden. Zum Beispiel erscheinen überspringbare Distanzen größer, wenn

Probanden zusätzliche Gewichte an ihren Knöcheln tragen (Lessard et al., 2009) oder das Tragen eines schweren Rucksacks lässt Hügel steiler und in weiterer Entfernung erscheinen (Proffitt et al., 2003; Witt et al., 2004). So können akute Veränderungen des körperlichen Zustands, zum Beispiel durch das Tragen eines Alterssimulationsanzuges, auch die strategischen Entscheidungen junger Erwachsener beeinflussen. Bei älteren Erwachsenen sind unterschiedliche Szenarien für ihre Entscheidungsfindung und Auswahl der Aufgabenschwierigkeit denkbar. Möglich wäre, dass sich ältere Erwachsene der Reduktion ihrer motorischen und kognitiven Fähigkeiten bewusst sind, und sich somit eher konservativ in ihrer Leistungsfähigkeit einschätzen. Es wurde jedoch gezeigt, dass ältere Erwachsene ihre Fähigkeiten in unterschiedlichen kognitiven Aufgaben überschätzen (Crawford & Stankov, 1996; Hansson et al., 2008; Shing et al., 2009). Auch hinsichtlich ihrer Fähigkeiten, Autozufahren (K. Wechsler et al., 2018; J. M. Wood et al., 2013) und anderer motorischer Aufgaben (Butler et al., 2015; Sakurai et al., 2013, 2014, 2017) haben ältere Erwachsene Überschätzungen der eigenen Fähigkeiten gezeigt. In den Studien von Sakurai und Kollegen (2013, 2014, 2017) sollten junge und ältere Erwachsene ihre Fähigkeiten bezüglich des Übersteigens eines Hindernisses (einer Latte) einschätzen. Bevor sie die Aufgabe physisch ausführten, sollten die Probanden aus einer Entfernung von 7 m einschätzen, welche Höhe sie sicher überqueren können. Danach wurden die Probanden gebeten die selbstgewählte Höhe zu übersteigen, und ihre tatsächliche Leistung wurde gemessen. Während junge Erwachsene eine Tendenz zur Unterschätzung ihrer Leistungsfähigkeit zeigten, überschätzte sich etwa ein Drittel der älteren Erwachsenen. Sie konnten die selbstgewählten Höhen nicht übersteigen. Die Tendenz war stärker bei älteren Erwachsenen, die einen inaktiven Lebensstil hatten (Sakurai et al., 2014) und wurde nicht durch die visuelle Höhenwahrnehmung beeinflusst (Sakurai et al., 2017). In der Studie von Butler et al. (2015) sollten ältere Erwachsene über Planken mit unterschiedlicher Länge, Höhe und Breite laufen. Der kürzeste Weg mit dem geringsten Risiko war über die schmalste und höchste Planke und der längste Weg über die breiteste und tiefste Planke zu gehen. Das Verhaltensrisiko wurde als die Wahrscheinlichkeit definiert, von der Planke zu fallen. Während Teilnehmer mit guten körperlichen Fähigkeiten angemessene Risiken auswählten, war die Schwierigkeitsauswahl der älteren Erwachsenen mit schlechten körperlichen Voraussetzungen schlecht auf ihre Fähigkeiten kalibriert. Sie wählten entweder zu schwierige Wege, mit einer erhöhten Wahrscheinlichkeit von der Planke zu fallen, oder zu leichte Wege, die kein Risiko beinhalteten.

Studien aus der kognitiv-motorischen Doppelaufgaben-Forschung zeigen hingegen, dass ältere Probanden bei körperlich anspruchsvollen und fordernden motorischen Aufgaben dazu neigen, diese bei der Ausführung zu präferieren (*posture-first*-Strategie: Al-Yahya et al., 2011; K. Z. H. Li et al., 2001; Lövdén et al., 2005; Lundin-Olsson et al., 1997; Ozdemir et al., 2016; Schaefer, 2014; Woollacott & Shumway-Cook, 2002). Diese Strategie wird anhand der

Doppelaufgaben-Kosten dargestellt, welche das Ausmaß der Leistungsreduktion in der Doppelaufgaben-Bedingung im Vergleich zur Leistung in der Einzel-Bedingung zeigen. In der Studie von K. Z. H. Li et al. (2001) sollten junge und ältere Probanden auf einem schmalen Pfad (teilweise mit Hindernissen) gehen und sich gleichzeitig Wortlisten einprägen. Der Pfad sollte möglichst schnell und akkurat durchlaufen und die auditiv präsentierten Wörter mithilfe einer zuvor trainierten Gedächtnisstrategie eingeprägt werden. Während der Ausführung in der Doppelaufgaben-Bedingung hatten die Probanden die Möglichkeit, externe kompensatorische Hilfsmittel (das Abstützen auf einem Geländer oder das Einfordern von zusätzlichen drei Sekunden beim Enkodieren der Wörter) zu benutzen. Die Doppelaufgaben-Kosten älterer Erwachsener waren im Vergleich zu den Kosten der jüngeren Erwachsenen viel höher in der Gedächtnisaufgabe, aber vergleichbar mit den Kosten der Jüngeren im Gehen. Die Autoren sehen in den Ergebnissen der älteren Probanden eine Priorisierung der motorischen Domäne, um zum Beispiel mögliche Stürze zu vermeiden. Die Zuhilfenahme des Geländers kann als adaptive Strategie der älteren Erwachsenen verstanden werden, die Leistung in der motorischen Aufgabe zu optimieren und die Risiken zu kontrollieren. Die vorgenannten Studien zeigen, dass neben den körperlichen Voraussetzungen und dem Lebensstil von älteren Erwachsenen auch die Charakteristik der Aufgabe eine Rolle bei der Selbsteinschätzung und Leistung älterer Erwachsener spielt. Für ältere Erwachsene ist es besonders wichtig, ihre Leistung in potenziell gefährlichen Situationen akkurat einschätzen und auch anpassen zu können.

Für Entwicklungspsychologen spielt die Frage, wie Individuen ihre Entwicklung regulieren, eine bedeutende Rolle. Im Rahmen des Modells *selection, optimization, and compensation*-Modells (Modell der Auswahl, Optimierung und Kompensation: Baltes, 1997; Freund & Baltes, 1998) haben Riediger et al. (2006) das Konzept der *selection margins* (Konzept der Auswahlspanne) vorgeschlagen. So können experimentelle Situationen geschaffen werden, in denen sich Probanden für einen geeigneten Aufgabenschwierigkeitsgrad entscheiden müssen. Mit Hilfe des Konzepts/Paradigmas erhält man Aufschluss über die verwendeten Strategien, nämlich ob die Probanden eher zum Über- oder zum Unterschätzen neigen. Das selection margins-Paradigma postuliert, dass es für jede Person ein optimales Niveau gibt, auf dem sie agieren kann. Dieses wird als *maximum manageable task-difficulty* (maximal beherrschbare Aufgabenschwierigkeit, [mmtd]) bezeichnet. Die Differenz zwischen der maximal beherrschbaren Aufgabenschwierigkeit und der selbstgewählten Aufgabenschwierigkeit, wird als *selection margins score* (Ergebnis der Auswahlspanne) bezeichnet. Progressive Auswahlspannen zeigen, dass Personen eine Aufgabenschwierigkeit wählen, die in Anbetracht ihrer Fähigkeiten zu hoch ist, und dass sie sich dadurch überschätzen. Konservative Auswahlspannen zeigen, dass Personen einen zu geringen Schwierigkeitsgrad wählen und somit ihre Leistung unterschätzen. Das Konzept der selection margins stammt ursprünglich aus der

Kognitionsforschung wurde jedoch auch schon vereinzelt bei motorischen Aufgaben angewandt (z. B. beim Seilspringen und Balldribbeln, siehe Schaefer et al., 2021).

Die Aufgabenschwierigkeit scheint ein Faktor zu sein, der die Selbsteinschätzung und damit auch das Wahlverhalten älterer Probanden bei motorischen Aufgaben beeinflusst. Mit Hilfe des selection margins-Modells sollte deshalb untersucht werden, ob motorische Aufgaben, die sich in ihrem körperlichen Risiko unterscheiden, zu unterschiedlichen Strategieentscheidungen bei älteren Erwachsenen führen. Außerdem sollte erforscht werden, inwiefern sich das Tragen eines Alterssimulationsanzuges auf die Verhaltensstrategien junger Erwachsener auswirkt (siehe Beitrag 2, Schaefer et al., 2022).

3.1.2 Möglichkeiten der Alterssimulation: Alterssimulationsanzüge

Die ersten Versuche einzelne, altersbedingte Verluste in der Sensorik und Motorik zu simulieren, reichen bis in die ´70er Jahre des vergangenen Jahrhunderts zurück. Mit Hilfe von Alltagsmaterialien wurden Einschränkungen der Sehkraft (z. B. Taucherbrille, Brille mit beklebten oder gelben Gläsern), des Hörens (z. B. Ohrstöpsel oder Kopfhörer), des Riech- und Geschmackssinnes (z. B. Nasenklammer), der Kinästhesie (z. B. Bandagen, Rollstuhl und Rotationsbrille) und des Tastsinnes (z. B. Gummihandschuhe, Fäustlinge, Wachs) nachgeahmt (Shore, 1976). Diese Simulationen sollten besonders jungen Menschen vermitteln, wie es sich anfühlt, alt zu sein. Eingesetzt wurden die ersten Formen der Alterssimulation vor allem in der Ausbildung von Ärzte- und Pflegeberufen, um das Empathievermögen für die späteren Patienten zu stärken (Babic & Crangle, 1987; Shore, 1976). Ferner wurden einzelne Komponenten, zum Beispiel spezielle Brillen oder Kopfhörer, schon früh dafür benutzt, den Einfluss sensorischer Einschränkungen auf kognitive und motorische Leistungen zu untersuchen (z. B. Ben-David & Schneider, 2010; Chapman & Hollands, 2006; Elliott et al., 1994; Lindenberger et al., 2001; Szafran, 1951).

Beispielsweise untersuchten Lindenberger und Kollegen (2001), ob simulierte Beeinträchtigungen der Seh- und Hörschärfe bei mittelalten Erwachsenen (30-50 Jahre) sowohl einen Einfluss auf die kognitiven Leistungen als auch auf die Kovariation zwischen sensorischen und kognitiven Funktionen haben, wie sie im Alter häufig zu finden sind (z. B. Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994). Hierfür benutzten sie aufsetzbare Brillengläser (partielle Okklusionsfilter), die durch Kontrastreduzierung die Sehschärfe beeinträchtigen und spezielle Kopfhörer, die zur Gesamtreduktion der Hörschärfe und der Absenkung von mäßig hohen Frequenzen führen. Die kognitiven Fähigkeiten wurden anhand einer computergestützten Testbatterie ermittelt (14 Tests), die die Dimensionen „Wahrnehmungsgeschwindigkeit“, „Logisches Denken“, „Episodisches Gedächtnis“, „Verbales Wissen“ und „Sprachkompetenz“ umfasste. Die Ergebnisse zeigen signifikante Beeinträchtigungen der Seh- und Hörschärfe durch die Simulationen, vergleichbar mit den Werten einer älteren Kontrollgruppe

(70-84 Jahre) ohne Einschränkungen. Die Einschränkungen der Seh- und Hörschärfe beeinträchtigten jedoch nicht die kognitive Leistungsfähigkeit der mittelalten Probanden. Die Autoren schließen aus den Befunden, dass der starke Zusammenhang zwischen sensorischer und kognitiver Leistung im Alter nicht auf eine Verringerung der sensorischen Schärfe zurückzuführen ist.

Szafran (1951) untersuchte vor 70 Jahren, inwiefern sich sowohl das Alter als auch die Reduktion visueller Informationen durch das Tragen einer Brille mit roten Gläsern auf die Leistung einer Zielaufgabe auswirken. Es wurde untersucht, wie Probanden unterschiedlichen Alters (20-60 Jahre, 10 Probanden pro Dekade) mit und ohne Einschränkung des Sehens mit der Hand verschiedene Positionen in ihrer Nähe im Raum lokalisieren können. Bei nichteingeschränkter Sicht benötigten die ältesten Probanden mehr Zeit, um ihre Zielbewegungen zu initiieren. Durch das Tragen der Brille wurde die Lokalisation der Ziele für die älteren Erwachsenen zudem bedeutsam erschwert. Der Autor schloss daraufhin auf eine größere Bedeutung visueller Hinweise für ältere Menschen bei der Durchführung von Zielbewegungen.

Seit einigen Jahrzehnten sind neben einzelnen Komponenten auch Ganzkörper Alterssimulationsanzüge in vielfältiger Ausführung und von verschiedenen Anbietern erwerbbar (Koken CO., 2005; Meyer-Hentschel, 2021; MIT AgeLab, 2019; Moll, 2021). Allen Modellen ist gemein, dass sie jungen Erwachsenen eine realistische und ganzheitliche Erfahrung des gesunden Alterns vermitteln sollen. Diese Ganzkörpererfahrung soll durch das gleichzeitige Tragen mehrerer Komponenten, die typische sensorische und körperliche Einschränkungen des Alters simulieren, ermöglicht werden. Die Hersteller der Anzüge verweisen darauf, dass die ausgewählten Komponenten entworfen wurden, um zum Beispiel der verminderten Kraft, Beweglichkeit und sensorischen Wahrnehmung im Alter zu entsprechen. Validierungsstudien oder empirische Belege, um ihre Argumente zu quantifizieren, liefern sie jedoch nicht. Neben Rollenspielen oder Simulationspuppen (siehe auch *Instant Aging*: Filz, 2009; Koytek, 2008; Kwetkat et al., 2011) sind Alterssimulationsanzüge eine Möglichkeit des Simulationstrainings, die im Gesundheitswesen, im medizinischen Bereich oder in der Pharmazie Verwendung findet (Braude et al., 2015; Fisher & Walker, 2013; Lee & Teh, 2020). In der allgemeinen Ausbildung von Ärzten, Krankenpflegern und Physiotherapeuten und im Besonderen in der Geriatrie ist die Nutzung von Alterssimulationsanzügen ein wesentlicher Bestandteil (als Review, siehe Eost-Telling et al., 2021; Giner Perot et al., 2020; Qureshi et al., 2017; Tremayne et al., 2011). Vordergründig soll der Einsatz der Anzüge jungen Auszubildenden oder Studierenden ein Gefühl für die körperlichen Herausforderungen von Patienten im fortgeschrittenen Alter vermitteln (Cheng et al., 2020; M. D. Wood, 2003). Der angestrebte Perspektivwechsel soll generell helfen, bei jungen Menschen negative Einstellungen bzw. Altersdiskriminierung gegenüber älteren Mitmenschen zu reduzieren (Green & Dorr, 2016). Gleichzeitig können durch die Anzüge Charakteristika bestimmter Krankheitsbilder (z. B. Seh- und Hörminderung, Arthritis, spastische Hemiparese, Diabetes mellitus oder Parkinson) erfahrbar gemacht und gleichzeitig Wissen über diese vermittelt werden (Clark et al., 1995; Filz, 2009; Koytek, 2008). Das Studiendesign sieht häufig vor, dass junge Probanden im Anzug alltägliche oder arbeitsspezifische Aufgaben absolvieren und anschließend einschätzen, wie sie das Tragen des Anzuges empfunden bzw. wahrgenommen haben (z. B. Qureshi et al., 2017; Tremayne et al., 2011). Neben dem Einsatz von Fragebögen werden so vor allem qualitative Daten, häufig durch Selbstberichte, über die Wirkung der Intervention erhoben.

In der Industrie und Wirtschaft können Alterssimulationsanzüge genutzt werden, um zum Beispiel Arbeitsplätze und -prozesse auf die Bedürfnisse älterer Arbeitnehmer anzupassen oder Produkte entsprechend den kognitiven und motorischen Fähigkeiten älterer Konsumenten zu entwickeln. In der Automobilbranche wurden Alterssimulationsanzüge verwendet, um die anspruchsvollen Fertigungsprozesse und zu erbringenden Leistungen im fortgeschrittenen Alter zu verdeutlichen (z. B. Schneider, 2011). Scherf (2014) evaluierte die Auswirkungen verschiedener Alterssimulationsanzug-Module auf die Montageleistung von jungen (20-30 Jahre alt) und älteren (50-60 Jahre alt) Montagearbeitern eines großen deutschen Automobilherstellers. Es zeigten sich vergleichbare Leistungen zwischen den jungen Arbeitern, die den am wenigsten einschränkenden Anzug trugen, und den älteren Arbeitern, die keinen Anzug trugen.

Wie sich das Tragen von Alterssimulationsanzügen auf die motorischen und körperlichen Leistungen junger Erwachsener auswirkt, wurde bisher in wenigen Studien mit unterschiedlichen Aufgaben untersucht (Lauenroth et al., 2017; Lavallière et al., 2016; Scherf, 2014; Zijlstra et al., 2016). Zijlstra und Kollegen (2016) untersuchten den Einfluss der Komplexität von Wegen und der körperlichen Alterung auf die Wegfindung. Die jungen Probanden (18-28 Jahre) führten verschiedene Wegfindungsaufgaben mit unterschiedlichen Komplexitätsanforderungen durch, bei denen sie teilweise einen gerontologischen Alterssimulationsanzug trugen. Die simuliert älteren Teilnehmer schnitten bei der Wegfindung in Bezug auf die Geschwindigkeit schlechter ab als die jungen Teilnehmer ohne Anzug. Darüber hinaus zeigte sich, dass simuliert ältere Personen im Vergleich zu jungen Personen während einer Orientierungsaufgabe höhere Herz- und Atemfrequenzen aufwiesen.

Lavallière et al. (2016) untersuchten, inwiefern das Tragen eines Alterssimulationsanzugs mehrere klinische Tests (Haltungsbalance, Nacken-/Schulterbewegungsfreiheit, Beweglichkeit des unteren Rückens/der hinteren Oberschenkelmuskulatur und 10-m-Gehen) und eine erfahrungsbezogene Lernaufgabe (Einkauf in einem Lebensmittelgeschäft) beeinflusst. Junge Erwachsene (20-29 Jahre), die den Simulationsanzug trugen, zeigten eine signifikante Verschlechterung in fast allen klinischen Tests, einschließlich einer verringerten Geschwindigkeit und einer erhöhten Anzahl von Schritten und Zeit, um die 10-Meter-Strecke zu gehen. Auch Lauenroth et al. (2017) untersuchten den Effekt eines Altersanzugs auf verschiedene

Gangparameter (Geschwindigkeit, Schrittlänge, Schrittzeit und Schrittbreite) und fanden bei den jungen Teilnehmern, die den Anzug trugen, im Vergleich zu älteren Erwachsenen eine Reduktion der Schrittlänge und -geschwindigkeit. Diese entspricht laut den Autoren einem simulierten Altersanstieg von 20 bis 25 Jahren.

Die angeführten Studien konnten Auswirkungen des Tragens eines Alterssimulationsanzuges auf ausgewählte motorische Leistungen, physiologische Parameter und Gangparameter bei jungen Erwachsenen zeigen. Weil die Studien jedoch selten einen Vergleich zu den respektiven Leistungen älterer Erwachsener beinhalten, mit Ausnahme von Lauenroth et al. (2017) und Scherf (2014), ist die Aussagekraft über die Beeinträchtigung der Leistungen der jungen Probanden weiterhin gering. Aus diesem Grund haben wir in einer Art Pilotstudie die Einflüsse eines Alterssimulationsanzuges auf die Leistungen junger Erwachsener in unterschiedlichen Funktionsbereichen (Motorik, Kognition und Wahrnehmung) quantitativ erhoben (siehe Beitrag 3, Vieweg & Schaefer, 2020).

3.1.3 Eigene Beiträge

3.1.3.1 Beitrag 3

Es wurde untersucht, wie sich das Tragen des Alterssimulationsanzuges GERT auf die Leistungen von jungen Erwachsenen in unterschiedlichen Bereichen (Motorik, Kognition und Wahrnehmung) auswirkt. Hierfür haben wir junge Erwachsene (N = 20, M_{Alter} = 22,3 Jahre) in einem Messwiederholungsdesign in verschiedenen grobmotorischen (*Functional Fitness*-Test, Rikli & Jones, 1999a, 1999b) und feinmotorischen Aufgaben (Hemdknöpfen und *Purdue Pegboard*-Test, Lafayette Instrument, 2015) sowie einem kognitiven Test (*Digit Symbol Substitution*-Test, D. Wechsler, 1981) geprüft. Weiterhin haben wir Veränderungen in ihrer Wahrnehmung hinsichtlich ihres körperlichen Zustandes (*Perceived Physical State*, Kleinert, 2006) und ihrer Stimmung (*Mood Scale*, Wilhelm & Schoebi, 2007) mit dem Einsatz entsprechender Fragebögen untersucht. Die Tests zur Fein- und Grobmotorik wurden gewählt, weil es für diese entsprechende Vergleichsnormen für ältere Erwachsene (Frauen und Männer im Alter von 60-89 Jahren) gibt, die wir für einen deskriptiven Vergleich herangezogen haben.

Die Ergebnisse zeigen, dass das Tragen des Alterssimulationsanzuges die Leistungen der jungen Erwachsenen in allen Bereichen deutlich einschränkt. Gleichzeitig ist das Ausmaß der Einschränkung von der jeweiligen Aufgabe und ihren Anforderungen abhängig. Für die unterschiedlichen Aufgaben der grobmotorischen Testbatterie (Arm- und Beinkraft, Schulter- und Hüftbeweglichkeit, aerobe Ausdauer und Gewandtheit) wurden Werte erzielt, die durchschnittlich einer prozentualen Verschlechterung im Bereich von 12-26 Prozent entsprechen. Im Vergleich zu den Normwerten der 60-89-Jährigen erzielten junge Erwachsene immer noch deutlich bessere Leistungen in den Bereichen Beinkraft, Hüftbeweglichkeit und Gewandtheit. Die Leistungen für die Aufgaben Armkraft und 2min-Steppen näherten sich den Leistungen der 60-64-Jährigen an, waren aber immer noch besser. Die Leistungen der jungen Erwachsenen in der Schulterbeweglichkeit-Aufgabe wurden durch das Tragen des Anzuges stärker beeinträchtigt und entsprechen ungefähr den Werten der 65-69-jährigen Frauen und Männer. Hinsichtlich der feinmotorischen Aufgaben reduzierte der Anzug die Leistungen der jungen Erwachsenen im Durchschnitt um 20-30 Prozent. Die Leistungen der Jungen im Anzug sind über alle Aufgaben des Purdue Pegboard-Tests hinweg (dominante Hand, nicht-dominante Hand, beide Hände und Montage-Aufgabe) in etwa vergleichbar mit den Leistungen von Frauen und Männern, die Ende siebzig bzw. Anfang achtzig sind. Die Ergebnisse des Kognitionstests zeigen, dass auch hier die Leistung der Jungen durch das Tragen des Anzuges eingeschränkt wird. Die Leistung im Digit Symbol Substitution-Test misst vornehmlich (visuelle) Wahrnehmungs- und Verarbeitungsgeschwindigkeit (S.-C. Li et al., 2004; D. Wechsler, 1981). Es ist wahrscheinlich, dass die schlechteren Leistungen durch die Beeinträchtigung des Sehens, aber auch durch eine behinderte motorische Ausführung zu Stande gekommen sind. Das Schreiben des Zielsymbols wird durch das Tragen der verschiedenen Handschuhe und eventuell auch durch die Gewichte an den Handgelenken wohl zusätzlich beeinträchtigt. Letztlich ist auch die aktuelle Wahrnehmung des eigenen Körpers und der Emotionen der jungen Erwachsenen durch das Tragen des Alterssimulationsanzuges negativ beeinflusst worden.

Fazit: Das Tragen eines Alterssimulationsanzuges beeinträchtigt die Leistungen junger Erwachsener in der Grob- und Feinmotorik sowie in der Kognition deutlich. Auch die Wahrnehmung des eigenen Körpers und der eigenen Emotionen wird durch den Anzug negativ beeinflusst. Das Ausmaß der Beeinträchtigung ist allerdings abhängig von der jeweiligen Aufgabe und generelle Aussagen des Herstellers, wie „der Anzug simuliert ein Altern von 30-40 Jahren“ (Moll, 2021) können durch die Ergebnisse nicht gestützt werden.

3.1.3.2 Beitrag 2

Mit Hilfe des selection margins-Konzepts wurde untersucht, inwiefern sich motorische Aufgaben, die in ihrer Wahrnehmung unterschiedliche körperliche Risiken haben, auf das Entscheidungsverhalten älterer und junger Erwachsener auswirken. Gleichzeitig sollte untersucht werden, ob die physischen Einschränkungen, die durch das Tragen eines Alterssimulationsanzuges (GERT) provoziert werden, auch die Strategieentscheidungen junger Erwachsener beeinflussen. Hierfür wurden die Ergebnisse zweier unabhängiger Testungen zusammengefasst. In beiden Testungen sollten junge und ältere Probanden eine motorische Aufgabe (Tablett-Tragen oder Übersteigen) absolvieren, bei der sie die Aufgabenschwierigkeit selbstständig wählen konnten. Die jungen Probanden absolvierten jeweils zwei Sitzungen, einmal mit und einmal ohne den Altersanzug (Messwiederholungsdesign). Die älteren Probanden absolvierten die Aufgaben stets ohne Altersanzug (eine Sitzung).

In Testung 1 sollten die Probanden (20 junge Erwachsene, M_{Alter} = 24.0, SD = 2.0 und 20 ältere Frauen, M_{Alter} = 71.8, SD = 8.6) mit Hilfe eines Tabletts einen Turm aus Holzklötzen (2,5 x 2,5 cm) transportieren. Letzterer wurde vom Versuchsleiter in der Mitte des Tabletts aufgebaut. Die Anzahl der Klötze bestimmte den Schwierigkeitsgrad der Aufgabe, da ein höherer Turm instabiler und somit schwieriger zu tragen ist. Das Tablett war auf einem Tisch platziert und sollte über eine Distanz von zwei Metern zu einem identischen Tisch getragen werden. Ziel der Aufgabe war es, möglichst viele Klötze zu transportieren, ohne dass der Turm dabei umfällt. Es war den Probanden nicht gestattet, die Holzklötze zu berühren. Die Zeit, die zur Bewältigung der Strecke benötigt wurde, wurde nicht gemessen. Entsprechend dem selection margins-Konzept wurde im Vor- und Nachtest die maximale Anzahl an Klötzen ermittelt (mmtd), die mindestens einmal erfolgreich von der Versuchsperson getragen werden konnte. Die Probanden absolvierten je zwei Versuche pro Schwierigkeitsstufe in einer festgelegten Reihenfolge. Jede Versuchsperson startete mit einem Turm aus fünf Klötzen und steigerte sich bis zu einem Turm aus 15 Klötzen. Die Werte der Vor- und Nachtests wurden für jeden Probanden gemittelt. In der Auswahlphase durften die Probanden eigenständig wählen, wie viele Klötze sie tragen wollten. In dieser Phase absolvierten sie 16 Versuche. Wenn sie den Turm erfolgreich von einem Tisch zum anderen tragen konnten, ohne dass er zusammenfiel, haben sie die Punktezahl entsprechend der Anzahl an Klötzen erhalten. Wenn der Turm zusammenfiel, haben die Probanden null Punkte erhalten. Die Versuchspersonen wurden instruiert, optimale Schwierigkeitsstufen zu wählen, um ihre Punktzahl zu maximieren. Auch die Werte der Auswahlphase (= Gesamtpunkte über 16 Versuche) wurden für jeden Probanden gemittelt. Die Ergebnisse der Studie zeigen, dass alle Probanden in der Lage waren, ihre Leistungen vom Vor- zum Nachtest zu verbessern. Insgesamt zeigten junge Probanden, auch im Altersanzug, bessere Leistungen als die älteren Probanden. In der Auswahlphase wählten alle Probanden Schwierigkeitsstufen, die unter ihren maximalen Leistungen lagen. Der Unterschied zwischen der maximal zu bewältigenden Aufgabenschwierigkeit einer Person (maximale Anzahl an Klötzen, die einmal getragen wurde) und ihrem selbstgewählten Schwierigkeitsgrad in der Auswahlphase, war bei jungen Erwachsenen größer als bei den älteren Erwachsenen. Diese trafen risikoreichere Entscheidungen, was sich auch an der höheren Anzahl an Nullpunkte-Durchgängen zeigt. Die Ergebnisse der Auswahlspanne unterschieden sich nicht zwischen den jungen Erwachsenen im und ohne Anzug. Junge Erwachsenen haben sich schnell an die physischen Einschränkungen gewöhnt und auch ihre Wahl der Schwierigkeitsstufen entsprechend angepasst.

In Testung 2 wurden 23 junge Erwachsene (M_{Alter} = 23,0, SD = 2,4) und 21 ältere Erwachsene (M_{Alter} = 71.9, SD = 2.4) getestet. Die Probanden unterschieden sich hinsichtlich ihrer Größe und ihres Gewichtes nicht signifikant voneinander. Ihre Aufgabe bestand darin, eine Querlatte zu übersteigen, ohne diese zu Fall zu bringen. Die Höhe der Latte bestimmte den Schwierigkeitsgrad der Aufgabe, da eine höhere Latte schwieriger zu übersteigen ist. Die Latte wurde zwischen zwei Stangen fixiert. Hierbei wurde sie auf hölzernen Auflegern positioniert und konnte so flexibel auf eine bestimmte Höhe eingestellt werden (ähnlich wie Konstruktionen im Hochsprung). Die Höhen konnten zwischen 44 cm (entspricht 1 Punkt) und 103 cm (entspricht 60 Punkten) variiert werden. Während der Vor- und Nachtests konnten die Probanden die Skalen an den Stangen nicht sehen, jedoch in der Auswahlphase. Die Latte wurde nicht an den Auflegern fixiert, so dass sie bei Berührung runterfallen konnte. Ältere Erwachsene wurden zusätzlich durch einen individuell einstellbaren Sicherheitsgurt gesichert, welcher an einer Metallkonstruktion befestigt wurde, um Stürze zu verhindern. Es wurden keine genauen Instruktionen zum Übersteigen der Latte gegeben, außer dass jede Art von Springen beim Überqueren untersagt war (ein Fuß musste immer den Boden berühren). Im Vor- und Nachtest wurde die maximale Höhe ermittelt (mmtd), die mindestens einmal erfolgreich von der Versuchsperson überstiegen werden konnte. Die maximalen Höhen wurden gemittelt und an der jeweiligen Beinlänge der Versuchsperson relativiert. Entgegen dem Vorgehen in Testung 1 (Tablett-Tragen) wurde zur Ermittlung der maximalen Höhe kein festes Vorgehen, sondern eine adaptive Ermittlung der Höhe gewählt. Nähere Information hierzu sind dem Methodenteil von Studie 2 (zu Testung 2) zu entnehmen. In der Auswahlphase absolvierten die Probanden 20 Versuche, in denen sie die zu übersteigende Höhe selbst auswählten. Konnten sie die Höhe erfolgreich übersteigen, erhielten sie die Menge an Punkten, die der Höhe entsprechen. Fiel die Latte herunter, erhielten sie null Punkte. Die Versuchspersonen wurden instruiert optimale Schwierigkeitsstufen zu wählen, um ihre Punktzahl zu maximieren. Auch die Werte der Auswahlphase (= Gesamtpunkte über 20 Versuche) wurden für jeden Probanden gemittelt und an der Beinlänge relativiert. Zusätzlich wurden noch weitere Maße zur kognitiven Verarbeitungsgeschwindigkeit, zur Körperwahrnehmung und zur Sehschärfe für die Fernsicht erhoben. Nähere Informationen zu diesen Tests und den zugehörigen Ergebnissen sind dem Ergebnisteil von Studie 2 (zur Testung 2) zu entnehmen. Die Ergebnisse zeigen, dass alle Probanden in der Lage waren, ihre Leistungen vom Vor- zum Nachtest zu verbessern. Das Tragen des Altersanzuges beeinträchtige die Leistungen der jungen Erwachsenen signifikant im Vor- und Nachtest. Im Vergleich zu den älteren Erwachsenen zeigten junge Probanden im Anzug vergleichbare Leistungen im Vor- und Nachtest. Das Tragen des Anzuges führte bei jungen Erwachsenen zu konservativeren Entscheidungen hinsichtlich ihrer Leistungsfähigkeit. Bezüglich der Differenz zwischen ihrer Maximalhöhe und ihrem selbstgewählten Schwierigkeitsgrad in der Auswahlphase (selection margins score), lagen junge Erwachsene im Anzug zwischen dem Niveau der älteren und der jüngeren Erwachsenen (ohne Anzug). Ältere Erwachsene waren vorsichtiger in ihren Wahlentscheidungen und neigten dazu, ihre Leistung stärker zu unterschätzen als junge Erwachsene (mit und ohne Anzug). In der Auswahlphase wählten alle Probanden Schwierigkeitsstufen, die unter ihren maximalen Leistungen lagen. Insgesamt waren Überschätzungen bei der beschriebenen Aufgabe selten, was sich auch in der niedrigen Anzahl an Nullpunkte-Durchgängen zeigt. Dabei scheint es sich um eine vernünftige Strategie zu handeln, da Stürze über die Latte vor allem für ältere Erwachsene ein größeres Risiko für ihre körperliche Gesundheit darstellen. Gleichzeitig ist es denkbar, dass ältere Probanden, die bereits Sturzerfahrungen hatten, diese Erinnerungen bei ihrer Wahlentscheidung mit einfließen haben lassen. Des Weiteren stellen die beiden Aufgaben auch unterschiedliche physische Anforderungen an die älteren Probanden, welche stärker bei der Übersteige-Aufgabe gewirkt haben könnten (z. B. Einschränkung des Gleichgewichts und der Beweglichkeit durch künstliche Knie- und Hüftgelenke).

Fazit: Junge und ältere Erwachsene unterscheiden sich in ihrer Auswahl der Aufgabenschwierigkeit je nach Art der motorischen Aufgabe. Gesunde, ältere Erwachsene können adaptiv ihre Wahlentscheidungen hinsichtlich motorischer Aufgaben anpassen, um körperlichen Risiken vorzubeugen. Das Tragen eines Alterssimulationsanzuges senkt nicht nur die motorischen Leistungen junger Erwachsener, sondern beeinflusst auch ihre Wahlentscheidungen.

3.2 Motorisches Lernen und Altern

Eine Definition der Motorik erweist sich als vielschichtig und umfasst unter anderem willkürliche als auch unwillkürliche Bewegungen sowie das Agieren des Menschen in der Umwelt und die gleichzeitige Interaktion mit dieser. Unter Bewegungen werden sowohl motorische Fertigkeiten (*motor skills*), als auch motorische Fähigkeiten (*motor abilities*) gefasst (Schmidt & Lee, 2005; Voelcker-Rehage, 2008). Bei motorischen Fertigkeiten müssen Bewegungen verschiedener Körperteile koordiniert werden, um das Bewegungsziel zu erreichen. Mit Hilfe von (viel) Übung können Fertigkeiten, wie das Klavierspielen, die Durchführung eines Tennisaufschlages, das Fahren eines e-Rollers oder klassische Grundbewegungsformen (Laufen, Springen und Werfen) erlernt werden. Motorische Fähigkeiten, wie die Ausdauer, Schnelligkeit, Koordination und Kraft, beziehen sich auf allgemeine Eigenschaften oder Fähigkeiten eines Individuums, die mit der Leistung einer Vielzahl von motorischen Fertigkeiten zusammenhängen (Voelcker-Rehage, 2008). Motorische Fertigkeiten können je nach Literatur einer bestimmten Klasse von zielgerichteten Bewegungsmustern zugeordnet und somit klassifiziert werden. So kann zwischen *diskreten* Bewegungen (mit einem festgelegten Anfang und Ende), kontinuierlichen Bewegungen (die Wiederholungen erfordern und bei denen Anfang und Ende nicht festgelegt sind), hinsichtlich der Bewegungsausführung unterschieden werden (Schmidt & Lee, 2005; Voelcker-Rehage, 2008). Auch nach dem Ausmaß der Muskelbeteiligung, das notwendig ist, um eine Fertigkeit auszuüben, kann unterschieden werden. Grobmotorische Bewegung erfordern eine hohe muskuläre Beteiligung (z. B. Ganzkörper- und/oder mehrgliedrige Bewegungen), wohingegen feinmotorische Bewegungen durch geringe Körperbewegungen gekennzeichnet sind und normalerweise auch die Manipulation von Werkzeugen oder Gegenständen beinhalten (Voelcker-Rehage, 2008). Ferner werden noch das Komplexitäts- und Schwierigkeitsniveau einer Aufgabe bzw. deren Durchführung unterschieden. Eine Bewegung wird zum Beispiel als komplex definiert, wenn sie nicht in einer einzelnen Sitzung erlernt werden kann, mehr als einen Freiheitsgrad hat und mehrere Teilsysteme oder Fähigkeiten bei der Ausführung beteiligt sind. Je höher der Komplexitätsgrad der Aufgabe, desto höher ist auch die Aufgabenschwierigkeit (Schmidt & Lee, 2005). Eine weitere Charakteristik ist der Bekanntheitsgrad (unbekannt/bekannt) der Bewegung/Aufgabe (Voelcker-Rehage, 2008). Durch die Kombination der vorgenannten Kategorien lässt sich eine hohe Aufgabenvariabilität erkennen, wenn es um Bewegungen im Allgemeinen geht. Die genannten Kategorien finden häufig auch Verwendung in der Forschung zum motorischen Lernen, welche ihrerseits abzugrenzen ist von den Forschungsbereichen zur motorischen Kontrolle (*motor control*) und der motorischen Entwicklung (*motor development*). Wie motorisches (Sequenz-)Lernen definiert ist und welche altersbedingten Unterschiede es beim Lernen motorischer Bewegungen oder Aufgaben gibt, soll Inhalt des folgenden Abschnitts sein.

3.2.1 Motorisches Sequenzlernen im Altersvergleich

Generell kann motorisches Lernen als ein Prozess verstanden werden, bei dem es um die Aneignung von (neuem) Wissen und (neuer) motorischer Fertigkeiten geht. Nach Schmidt und Lee (2005, S. 302) kann motorisches Lernen wie folgt definiert werden: „Motor Learning is a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement." Vier Aspekte sind in dieser Definition besonders hervorzuheben. Schmidt und Lee verstehen motorisches Lernen als einen Prozess, bei dem die Befähigung erworben wird, geübte motorische Bewegungen bzw. motorische Fertigkeiten ausführen zu können. Motorisches Lernen entsteht als direktes Ergebnis von Übung und Erfahrung. Es kann nicht direkt beobachtet werden, aber es kann aufgrund von stattgefunden Verhaltensänderungen auf Lernprozesse geschlussfolgert werden. Letztendlich wird davon ausgegangen, dass motorisches Lernen relativ dauerhafte Veränderungen in der Befähigung zu motorischen Bewegungen bzw. Fertigkeiten hervorruft. Schmidt und Lee weisen darauf hin, dass es beim Üben und Erwerben motorischer Fertigkeiten beim Menschen vor allem darum geht, die Natur zugrundeliegender interner Prozesse und Zustände zu verstehen. Unter internen Prozessen sind Veränderungen im Zentralnervensystem zu verstehen, wie Änderungen in der Art und Weise der Organisation sensorischer Informationen oder Veränderungen im Muster der Muskelaktivität. Demnach steht beim Lernen die Frage nach dem „wie" und „was" im Fokus. In einer weiteren Definition von Krakauer et al. (2019) geht es bei der Aneignung einer motorischen Fertigkeit darum, in einem bestimmten Aufgabenkontext schnell ein geeignetes Bewegungsziel zu identifizieren, zur richtigen Zeit die richtige Aktion auf einen sensorischen Reiz und/oder den aktuellen Zustand des Körpers/der Welt auszuwählen und diese

Aktion (Bewegung) genau und präzise auszuführen. Beispielsweise müssen bei der Zubereitung einer Tasse Kaffee oder der Eingabe des Pins einer Geldkarte einzelne Bewegungsaktionen in einer bestimmten zeitlichen Reihenfolge durchgeführt werden, um das Bewegungsziel zu erreichen. Das Erlernen einer motorischen Sequenzaufgabe erfordert demnach die Informationsverarbeitung über die räumlichen Positionen der Ziele, die Planung und Organisation der Elemente in der Sequenz und der erforderlichen Bewegungskommandos sowie die Ausführung der geplanten Aktionen (Shea et al., 2019).

In den letzten Jahrzehnten war das motorische Sequenzlernen bei jungen und älteren Erwachsenen oft Gegenstand der Motorikforschung. Altersbedingte Leistungseinbußen wurden in unterschiedlichen Aufgaben gefunden (Goggin & Meeuwsen, 1992; Panzer et al., 2011; Seidler, 2006; Verwey, 2010; als Review, siehe Voelcker-Rehage, 2008; Welsh et al., 2007). Aufgaben aus dieser Forschungsrichtung umfassen typischerweise Fingerdrücke auf Knöpfe von Antwortboxen oder Tasten einer Tastatur (z. B. Barnhoorn et al., 2016, 2019), Bewegungen eines Hebels mit der Hand oder dem ganzen Arm (z. B. Panzer et al., 2011, 2014) sowie das Erzeugen isometrischer Kräfte, zum Beispiel mit den Fingern (z. B. Hübner et al., 2019; Vieluf et al., 2015). Verwey (2010) verwendete zum Beispiel eine Aufgabe, bei der eine Sequenz über diskrete Fingerbewegungen produziert wird (*discrete sequenze production*-Aufgaben; als Review, siehe Abrahamse et al., 2013), um das Gruppieren von Untersequenzen bei jungen und älteren Erwachsenen zu untersuchen. Bei dieser Aufgabe wurden den Probanden visuelle Reize auf einem Bildschirm präsentiert und sie sollten so schnell wie möglich die räumlich zugeordnete Taste zum angezeigten Stimulus drücken. Die Ergebnisse zeigten, dass die langsamere Sequenzausführung bei den älteren Erwachsenen im Vergleich zu jüngeren Erwachsenen mit einer eingeschränkten Gruppierung von motorischen Untersequenzen verbunden war.

Curran (1997) untersuchte die Sequenzlernfähigkeit älterer Menschen mit Hilfe von sich wiederholenden oder zufälligen Tastendruck-Sequenzen. Die jungen und älteren Probanden hatten die Aufgabe, so schnell und genau wie möglich durch kontinuierliches Drücken der räumlich entsprechenden Taste auf visuell präsentierte Reize zu reagieren, die ihnen auf einem Computerbildschirm gezeigt wurden (*serial reaction time*-Aufgaben; siehe auch Nissen & Bullemer, 1987). Die gefundenen Unterschiede im Sequenzlernen, mit langsameren und ungenaueren Ausführungen der Sequenzen der älteren Probanden führte er auf ihr beeinträchtigtes Gruppierungsverhalten (*chunking*) zurück. Die jungen Erwachsenen waren hingegen in der Lage, längere Subsequenzen zu formieren. Shea et al. (2006) verwendeten dynamisch auszuführende Bewegungssequenzen mit mehreren Elementen (wiederholte vs. zufällige Sequenz), um altersbedingte Effekte beim motorischen Lernen zu untersuchen. Junge und ältere Probanden bewegten einen Hebel mittels Extensions-/Flexionsbewegungen des Unterarms so schnell und reibungslos wie möglich zu visuell präsentierten Zielen. Es zeigte sich, dass junge

Erwachsene die wiederholte Sequenz in der Aneignung und beim Retentionstest (Lerntest) wesentlich schneller ausführten als die älteren Erwachsenen.

Die zuvor genannten Aufgaben verdeutlichen, dass die Einschränkung des motorischen Lernens im fortgeschrittenen Alter für eine Vielzahl von motorischen Aufgaben gilt. Diese unterscheiden sich in ihren Eigenschaften, wie der Bewegungsdauer, den Bewegungsfreiheitsgraden oder hinsichtlich Kontroll- und Rückmeldungsprozessen (Curran, 1997; Kovacs et al., 2009; Krakauer et al., 2019). Im Allgemeinen kann zusammengefasst werden, dass Bewegungsausführungen mit zunehmenden Alter langsamer, variabler und weniger harmonisch sind (Chaput & Proteau, 1996; Panzer et al., 2011; Pohl et al., 1996; siehe Leinen et al., 2016; Vieluf et al., 2017 für den *lifespan*-Ansatz). Die Gründe für die regressiven, altersbedingten Leistungen in der Motorik und im motorischen Lernen sind sehr vielfältig. Stark vereinfacht gesagt können die Ursachen eher in „peripheren Prozessen" oder eher in „zentralnervösen Prozessen" liegen. Wie bereits in Kapitel 3.1.1 beschrieben, durchläuft der Körper mit fortschreitendem Alter eine Vielzahl von Veränderungen. Neben der nachlassenden Muskelkraft und der schwindenden Schnelligkeit verändert sich auch die Koordinationsfähigkeit bei älteren Erwachsenen. Dies kann zu Schwierigkeiten in der angemessenen Kontrolle von Agonisten und Antagonisten führen und so zu Problemen bei der Koordination einzelner Teilbewegungen oder der kompletten Bewegungsausführung. Obwohl einige degenerative physiologische Faktoren bekannt sind (z. B. Sarkopenie, reduzierte und variablere synaptische Inputs, weniger stabile neuromuskuläre Verbindungen und kleinere und langsamere Skelettmuskelfasern) reichen diese allein nicht aus, um die vielfältigen Leistungsunterschiede im motorischen Verhalten zwischen Jung und Alt zu erklären. Kognitionspsychologen und Theoretiker aus der Bewegungsforschung sehen die (senso-)motorischen Verhaltensunterschiede auch in der Veränderung zentraler kognitiver Prozesse begründet (Cai et al., 2014; Verhaeghen & Salthouse, 1997; Voelcker-Rehage, 2008). Für sie besteht ein Zusammenhang zwischen den nachlassenden kognitiven Funktionen und motorischen Leistungen bei älteren Erwachsenen. Bo und Kollegen (2009) beobachteten für ältere Erwachsene eine Korrelation zwischen der visuell-räumlichen Arbeitsgedächtniskapazität und der Länge von motorischen Untersequenzen (*motor chunks*). Darüber hinaus zeigten ältere Erwachsene im Vergleich zu jungen Erwachsenen eine allgemeine Verringerung der Arbeitsgedächtniskapazität, als auch kürzere motorische Untersequenzen. Auch die Ergebnisse von Panzer et al. (2011) zeigten, dass die allgemeine Verlangsamung bei der Ausführung einer 16-elementigen Bewegungssequenz bei älteren Menschen darauf zurückzuführen zu sein scheint, dass sie der Sequenz keine Struktur auferlegen konnten. Im Vergleich zu den jüngeren Probanden legen die relativ langsamen Reaktionen der älteren Erwachsenen auf jedes Element der Sequenz nahe, dass sie die Sequenz als diskrete Bewegungen produzierten und keine Untersequenzen bildeten. In einer weiteren intermanuellen Übungsstudie von Panzer et al. (2014) sollten junge und ältere

Probanden ein einfaches räumlich-zeitliches Muster erlernen. Dabei führten die Teilnehmer über zwei Tage Flexions- und Extensionsbewegungen mit ihrem linken und rechten Arm aus, in einer Bewegungszeit von 1300 ms. Die Ergebnisse der Studie zeigten, dass ältere Erwachsene Probleme bei der Entwicklung einer effektiven (kognitiven) Repräsentation der Bewegungssequenz haben. Zudem waren sie weniger genau in ihrer räumlichen Leistung als junge Erwachsene. Die Autoren gehen davon aus, dass ältere Erwachsene beim Erlernen von Bewegungssequenzen eher zu *closed loop*-Kontrolle neigen. Closed loop-Prozesse beschreiben bei längeren Bewegungszeiten das Vorhandensein und die Verarbeitung von Rückmeldungen in einem Regelkreisprinzip (Adams, 1971). Schon während der Bewegungsausführungen wird visuelles und propriozeptives Feedback verarbeitet und mit dem Bewegungsplan, der vor der Ausführung generiert wurde, abgeglichen. Anhand dieses Abgleichs wird eine ständige Fehlerschleife durchlaufen, die Fehlerkorrekturen während der Bewegungsausführung ermöglicht (Adams, 1971; Ivry, 1994). Man spricht auch davon, dass die Bewegung *online* kontrolliert wird. Aufgrund der längeren Bewegungsdauer können so Rückmeldungsschleifen, die zur Steuerung der Bewegung benötigt werden geschlossen werden, und dies ermöglicht Korrekturen und eine Überwachung des Bewegungsfortschrittes während der Ausführung ("im Flug", Bastian, 2006; Glover, 2004). Motorische Sequenzen mit kürzeren Bewegungsdauern werden hingegen überwiegend durch *open loop*-Prozesse gesteuert. Aufgrund der kürzeren Bewegungsdauer werden die Bewegungen vor der Ausführung geplant (*pre planned*) und regulatorische Anpassungen durch Feedbackverarbeitung werden in der Regeln nicht durchgeführt (Adams, 1971). Pre planned-Prozesse beinhalten die Auswahl und Programmierung der zur Bewegungsdurchführung notwendigen Informationen, wie das Timing und die Geschwindigkeit der Bewegung (Glover, 2004). Sobald die Bewegung ausgeführt wird, kann der Ablauf nicht mehr verändert bzw. korrigiert werden. Erst die Bereitstellung des Handlungsergebnisses nach der Bewegungsausführung ermöglicht es, Korrekturen zu planen und bei der nächsten Ausführung vorzunehmen. Bei Bewegungen von kurzer Dauer, bei denen die Zeit zur Durchführung begrenzt ist, induzieren die Planung und Durchführung der Bewegungssequenz gleichzeitige Verarbeitungsprozesse. Nach der *Processing-Speed*-Theorie von Salthouse (1996) ist anzunehmen, dass bei älteren Erwachsenen eine der relevanten Operationen (Planung oder Durchführung) verlangsamt ausgeführt und so die Menge gleichzeitig vorhandener Informationen reduziert wird. Für eine erfolgreiche Verarbeitung in der zur Verfügung stehenden Zeit wären jedoch mehr Informationen notwendig. Dass die Verarbeitungsgeschwindigkeit mit zunehmendem Alter generell zurückgeht, ist bestens belegt (Salthouse, 1996, 2000; Shea et al., 2019).

Verneau et al. (2014) verwendeten eine Variante einer seriellen Reaktionszeitaufgabe, um die Effekte von unterschiedlichen Bewegungszeiten auf implizites und explizites Bewegungssequenzlernen bei älteren Erwachsenen zu untersuchen. Sie fanden, dass ältere

Erwachsene beim Ausführen einer expliziten Sequenzlernaufgabe von einer reduzierten Zeitbeschränkung (längere Intervalle zwischen der Reaktion und dem nachfolgenden Reiz) profitierten. Ähnliches konnten Starns und Ratcliff (2010) für kognitive Aufgaben (Diskriminierung & Gedächtnis) zeigen. Ältere Erwachsene nahmen sich vor der Durchführung mehr Zeit als junge Erwachsene, um die erforderlichen Informationen zu sammeln. Die Autoren schlussfolgerten daraus, dass sich ältere Erwachsene mehr auf Genauigkeit und darauf, Fehler zu vermeiden, fokussieren als auf Geschwindigkeit (Salthouse, 2000; Starns & Ratcliff, 2010). Es kann angenommen werden, dass ältere Erwachsene auch beim Erlernen motorischer Sequenzbewegungen von einer reduzierten Zeitbeschränkung profitieren. Denkbar wäre, dass eine verlängerte Zeit zur Bewegungsausführung die Wahrscheinlichkeit erhöht, dass die Probanden genügend Zeit haben, die Regelkreisprozesse zur Verarbeitung visueller und propriozeptiver Rückmeldung zu schließen, und somit auch Korrekturen während der Bewegungsausführung durchführen können. Ältere Probanden könnten ihren Fokus dann eher auf die Genauigkeit der Bewegungsausführung legen.

Aus den zuvor genannten Ergebnissen und Annahmen leiteten sich das Studiendesign und die Hypothesen für Beitrag 4 (Vieweg et al., 2020) ab. Zum einen sollte untersucht werden, wie sich eine systematische Verlängerung der Bewegungszeit auf das Sequenzlernen bei jungen und älteren Probanden auswirkt. Zum anderen wollten wir untersuchen, wie der kognitive Status von älteren Erwachsenen mit ihrer motorischen Lernleistung kovariiert. Der zweite Aspekt beinhaltet dabei die Frage, welche Rolle kognitive Prozesse beim Erlernen einer Bewegungssequenz spielen. Dabei geht es hinsichtlich der älteren Erwachsenen um den Einfluss kognitiver Funktionen auf altersbedingte Leistungseinbußen beim motorischen Sequenzlernen.

Mit Beitrag 1 (Vieweg et al., 2022) sollte hingegen untersucht werden, wie sich periphere Einschränkungen in Form eines Alterssimulationsanzuges auf die motorische Lernleistung von jungen Erwachsenen auswirken. Welche Bedeutung den peripheren Einschränkungen beim Sequenzlernen zukommt, sollte im Vergleich zu den Leistungen älterer Erwachsener betrachtet werden. Des Weiteren sollte untersucht werden, welche Rolle zentrale Informationsverarbeitungsprozesse beim motorischen Sequenzlernen spielen, und ob sie bei älteren Erwachsenen Leistungseinbußen in der motorischen Leistung mit erklären können. Beide Studien sollen einen Beitrag zur Debatte über gemeinsame oder spezifische Ursachen für regressive Leistungen im Alter liefern.

3.2.2 Eigene Beiträge

3.2.2.1 Beitrag 4

Hier sollte untersucht werden, ob ältere Erwachsene beim motorischen Sequenzlernen davon profitieren, wenn ihnen mehr Zeit für die Ausführung einer Bewegungssequenz zugestanden wird. Gleichzeitig wollten wir evaluieren, ob der kognitive Status einer älteren Person – also ihre aktuellen kognitiven Fähigkeiten – einen Einfluss auf ihre motorische Lernleistung (Retentionstest) hat. Dafür sollten junge ($N = 28$) und ältere Erwachsene ($N = 28$) eine Bewegungssequenz erlernen, die aus Flexions- und Extensionsbewegungen des Ellbogens besteht. Die Probanden wurden zufällig auf zwei Übungsbedingungen, die sich hinsichtlich der Zeit zur Bewegungsausführung unterschieden, verteilt. Eine Übungsbedingung erlaubte es den Probanden (14 junge und 14 ältere Erwachsene) die Bewegungssequenz in 1300 ms durchzuführen, während die andere Bedingung 2000 ms zur Bewegungsausführung erlaubte (14 junge und 14 ältere Erwachsene). Während der Testung saßen die Probanden auf einem höhenverstellbaren Stuhl, und ihr dominanter rechter Arm lag auf der Hebel-Apparatur (einer Schiene mit Griff) auf. Ihr Blick war auf die Projektion auf der Wand vor ihnen gerichtet. Zur visuellen Rückmeldung wurde ein Cursor gezeigt, der die Position des Arms/Hebels darstellte. Sobald die Probanden den Cursor über den Startpunkt führten, verschwand das gezeigte Zielmuster und es war nur noch der Cursor zu sehen. Die Aufgabe der Teilnehmer bestand darin, den Hebel in horizontaler Ebene über Extensions- und Flexionsbewegungen (3 Umkehrpunkte: Änderung der Bewegungsrichtung von Extension zu Flexion und umgekehrt) so zu steuern, dass sie das zuvor gezeigte Zielmuster möglichst exakt reproduzieren konnten. Die Abweichung zwischen dem räumlich-zeitlichen Zielmuster und der Trajektorie der eigenen Bewegung sollte so gering wie möglich gehalten werden, um einen geringen Fehlerwert zu produzieren (*root mean square error* [RMSE]). In den RMSE fließen die Abweichungen als räumlicher (Amplitude) und zeitlicher Fehler ein. Nach Beendigung eines Versuches wurde den Versuchspersonen als Rückmeldung zusätzlich zum Zielmuster ihre eigene Bewegungstrajektorie und der RMSE gezeigt. Weiterhin wurde der *Harmonicity*-Wert, als Maß für die Gleichmäßigkeit der Bewegungsausführung ermittelt. Für den Retentionstest wurden ferner der absolute konstante Fehler für die räumliche Abweichung (*ACE amplitude*) und zeitliche Abweichung (*ACE timing*) zu den drei Umkehrpunkten der Bewegungssequenz ermittelt.

Nach der Aneignung der Bewegungssequenz an Tag 1 (99 Versuche), folgten an Tag 2 der Retentionstest (10 Versuche) und die Ermittlung des kognitiven Status (*Montreal Cognitive Assessment* [MoCA]). Mit dem MoCA-Test kann der kognitive Status einer Person ermittelt werden, indem über Aufgaben zu verschiedenen kognitiven Funktionen (Aufmerksamkeit, Arbeitsgedächtnis, exekutive Funktionen und visuell-räumliche Fähigkeit) eine Gesamtpunktesumme gebildet wird. Die Korrelation zwischen der Lernleistung der motorischen Sequenzaufgabe (Retentionstest) und dem MoCA-Wert wurde für alle jungen und älteren Probanden getrennt berechnet. Es zeigte sich, dass alle Probanden ihre Leistung über die Aneignung verbesserten. Die jungen Probanden produzierten hierbei in beiden Übungsbedingungen geringere Abweichungen und damit Fehlerwerte (RMSE) als die älteren Probanden. Beide Altersklassen profitierten in der Aneignung von der längeren Ausführungszeit (2000 ms-Bedingung), indem sie geringere Fehlerwerte produzierten. Dieses Ergebnismuster zeigte sich allerdings nicht für den Retentionstest, der als Lernmaß gilt. Hier gab es keinen signifikanten Unterschied zwischen den beiden Ausführungs-Bedingungen. Der Alterseffekt, mit besseren Leistungen der jungen Probanden im Vergleich zu den älteren, blieb für den Retentionstest bestehen. Die genauere Betrachtung des zeitlichen und räumlichen Fehlers (ACE timing und ACE amplitude) zeigte, dass ältere Erwachsene zu den Umkehrpunkten eins und zwei größere Amplitudenfehler und zum Umkehrpunkt drei größere zeitliche Fehler produzierten, als die jungen Probanden. Für die älteren Erwachsenen korrelierte die Lernleistung im Retentionstest (RMSE) signifikant negativ mit dem erzielten MoCA-Wert. Die Korrelation zeigt, dass ältere Erwachsene mit einem besseren kognitiven Status auch bessere Leistungen in der Ausführung der Bewegungssequenz zeigen. In Anlehnung an die Studie von Panzer et al. (2014) zeigen die Ergebnisse, dass auch eine verlängerte Bewegungszeit (2000 ms) für ältere Erwachsene nicht ausreichend zu sein scheint, um eine einfache Bewegungssequenz in einem geschlossenen Regelkreis kontrollieren und spezifizieren zu können.

Fazit: Mehr Zeit zur Bewegungsausführung verbessert die Aneignungsleistung, aber nicht das Sequenzlernen bei älteren Erwachsenen, im Vergleich zu jungen Erwachsenen. Kognitives Altern steht teilweise im Zusammenhang mit dem schlechteren motorischen Sequenzlernen bei älteren Erwachsenen.

3.2.2.2 Beitrag 1

An der Untersuchung nahmen insgesamt 23 junge Erwachsene (M_{Alter} = 23,4, SD = 3,4) und 23 ältere Erwachsene (M_{Alter} = 72,6, SD = 4,6) teil. 12 der jungen Erwachsenen führten die Testung im Alterssimulationsanzug (GERT) und 11 ohne den Altersanzug durch. Die älteren Probanden absolvierten die Testung ohne den Anzug. Die Aufgabe bestand darin, mit dem dominanten rechten Arm eine Sequenz von Extensions- und Flexionsbewegungen in horizontaler Ebene durchzuführen. Die Ausführungsdauer wurde konstant gehalten und betrug 1300 ms. Der Arm lag während der Ausführung auf einer Hebel-Apparatur auf. Ziel war es, die Bewegungssequenz so auszuführen, dass die Abweichung der eigenen Bewegungstrajektorie zum vorgegebenen Zielmuster so gering wie möglich ist. Die Abweichung wurde über den RMSE berechnet. Das Zielmuster wurde auf eine Wand vor den Probanden projiziert. Zu beachten ist, dass das Zielmuster verschwand, sobald die Teilnehmer den Versuch vom Startpunkt initiierten. Zu diesem Zeitpunkt sahen sie nur noch den Cursor an der Wand, der die aktuelle Position des Hebels/Arms repräsentiert. Nach Beendigung jedes Versuchs erhielten die Probanden visuelle Rückmeldung in Form ihrer eigenen Bewegungstrajektorie, des Zielmusters und des RMSE.

Die Aneignung des räumlich-zeitlichen Musters bestand aus 11 Blöcken (je 9 Versuche) und der Retentionstest wurde am darauffolgenden Tag absolviert (10 Versuche).

Zusätzlich wurden kognitive Maße (*Digit Symbol Substitution*-Test [DS] und *Figural Speed*-Test [FS]) sowie ein Sehtest für die Weitsicht erhoben. Sowohl der DS als Papier-und-Stift-Test als auch der FS als Computertest messen die (perzeptuelle) Verarbeitungsgeschwindigkeit. Für Jung (mit und ohne Anzug zusammen) und Alt wurden die Korrelationen zwischen der motorischen Lernleistung (Retentionstest) und den kognitiven Maßen (DS score, FS Fehler und Reaktionszeiten) separat berechnet. Die jungen Erwachsenen führten alle Aufgaben (motorisches Sequenzlernen, DS, FS und der Sehtest) entweder im Altersanzug (n = 12) oder ohne Anzug (n = 11) durch. Über die Aneignung zeigten alle Probanden eine Verbesserung ihrer Leistungen in der motorischen Sequenzaufgabe. Beide jungen Erwachsenen-Gruppen zeigten sowohl in der Aneignung als auch im Retentionstest bessere Leistungen als die älteren Probanden. Gleichzeitig unterschieden sich die Gruppen der jungen Erwachsenen weder in der Aneignung noch im Retentionstest signifikant voneinander. Die jungen Erwachsenen im Anzug waren innerhalb der ersten Versuche der Aneignung in der Lage, sich an die physischen Restriktionen des Anzuges anzupassen. Wie angenommen zeigte der Sehtest (für die Weitsicht) schlechtere Werte für die jungen Erwachsenen im Anzug im Vergleich zu ihrer Altersgruppe ohne Anzug. Interessanterweise unterschieden sich hier die Werte der jungen Probanden im Anzug nicht signifikant von denen der älteren Erwachsenen. Hinsichtlich der Ergebnisse der kognitiven Tests zur Verarbeitungsgeschwindigkeit unterschieden sich die beiden jungen Erwachsenen-Gruppen nicht, letztere zeigten jedoch bessere Leistungen als die älteren Probanden (mit Ausnahme der Fehler im FS). Die Ergebnisse der Korrelationen zeigen, dass die Leistung in den kognitiven Tests bei älteren Erwachsenen mit der Leistung beim motorischen Lernen kovariiert, jedoch nicht bei jungen Erwachsenen. Für die älteren zeigt sich dies in der negativen Korrelation zwischen dem DS score und der Retentionstestleistung sowie in der positiven Korrelation zwischen den Fehlern im FS und den RMSE des Retentionstests.

Fazit: Das Tragen eines Alterssimulationsanzuges beeinflusst bei jungen Erwachsenen nicht das Lernen einer einfachen motorischen Sequenzaufgabe. Die motorische Lernleistung der Jungen im Anzug übertrifft auch weiterhin die Leistung der älteren Erwachsenen. Die Schärfe der Fernsicht erfährt starke Beeinträchtigungen durch das Tragen des Anzuges. Bei älteren Erwachsenen gibt es eine enge Wechselwirkung zwischen kognitivem Altern und Defiziten im motorischen Lernen, die anhand der Geschwindigkeit von Informationsverarbeitungsprozessen aufgezeigt werden kann.

4 Diskussion

4.1 Möglichkeiten der Alterssimulation

Der aktuelle Forschungsstand zeigt, dass sich der Einsatz von Altersanzügen als Lehr- und Lernmethode vor allem in Gesundheitsberufen etabliert hat. In einer systematischen Übersichtsarbeit von Tullo et al. (2010) heißt es, dass innovative Unterrichtsmethoden (z. B. Altersanzüge) das Potenzial haben, das Wissen und die Einstellung junger Medizinstudenten gegenüber älteren Patienten zu verbessern und Empathie und Perspektivenübernahme in diesen Berufen zu fördern. Allerdings werden Altersanzüge als Simulationsmethode auch kritisch hinsichtlich der Wirksamkeit in der geriatrischen, medizinischen Ausbildung hinterfragt (z. B. Alfarah et al., 2010). Anliegen dieser Arbeit war es jedoch herauszufinden, ob es durch das Tragen des Altersanzuges GERT zu Ähnlichkeiten in motorischen und kognitiven Leistungen, beim motorischen Lernen oder bei der Wahl von Aufgabenschwierigkeiten zwischen jungen und älteren Erwachsenen kommen kann. Die Ergebnisse der eigenen Studien weisen darauf hin, dass es die Alterssimulation erlaubt, mehr über die peripheren Gründe von Leistungsverschlechterungen im Alter herauszufinden. Die Befunde zeichnen jedoch kein einheitliches Bild und werden im Folgenden differenziert betrachtet.

Zu den Limitationen von Alterssimulationsanzügen zählt sicherlich, dass das Tragen eines Alterssimulationsanzuges eine kurzfristige Intervention ist, die nicht gleichzusetzen ist mit dem langfristen Alterungsprozess, den ältere Menschen über Jahrzehnte durchlaufen. Das Altern ist ein Prozess, der durch große interindividuelle Unterschiede in den körperlichen und kognitiven Fähigkeiten oder auch Einschränkungen zwischen älteren Erwachsenen geprägt ist. Auch beim gesunden Altern verändert sich der Körper älterer Menschen allumfassend und kontinuierlich. Bestimmte Ereignisse, wie Unfälle oder Erkrankungen, können diesen Prozess beschleunigen, aber er kann auch verlangsamt werden, zum Beispiel durch einen körperlich aktiven Lebensstil (Hollmann et al., 2007). Mit der Zeit lernen ältere Personen mit ihren aktuellen Fähigkeiten umzugehen und können so auch Strategien entwickeln, die sich sowohl in angepasstem Verhalten (z. B. durch Kompensation, siehe Baltes & Baltes, 1990) oder auch in Vermeidungsstrategien (z. B. bei Stürzen, siehe Rubenstein, 2006) äußern können. Die Ergebnisse der Studie 2 (Schaefer et al., 2022) und 1 (Vieweg et al., 2022) zeigen hingegen, dass junge Probanden im Anzug (sehr) schnell in der Lage waren, ihre körperlichen Einschränkungen wahrzunehmen, und dadurch sowohl ihre Leistungsprognosen als auch ihre Handlungen anpassen konnten. Eine interessante Frage ist, ob die veränderte Selbstwahrnehmung (Studie 2 & 3) sowie die Änderungen in den Leistungsprognosen der jungen Erwachsenen im Anzug (Studie 2) auch durch Altersstereotype hervorgerufen wurden. Altersstereotype können verschiedene kognitive und motorische Leistungen (Bock & Akpinar, 2016; Hausdorff et al., 1999; Hess et al., 2003; als Review siehe Meisner, 2012), aber auch die Motivation und

Anstrengungsbereitschaft beeinflussen (Hess et al., 2016, 2019). Sie sind meist negativ konnotiert. Durch die Benennung des Anzuges als Alterssimulationsanzug könnten bei den jungen Erwachsenen negative Altersstereotype hervorgerufen werden. Die Konfrontation mit den verschiedenen sensorischen und motorischen Einschränkungen des Altersanzuges könnten bei ihnen mit negativen Emotionen oder Bedenken hinsichtlich des eigenen zukünftigen Alterungsprozesses verknüpft werden. Zukünftige Studien sollten untersuchen, ob eine andere Benennung des Altersanzuges, zum Beispiel als „Herausforderungsanzug“ oder als „Anzug zur Beeinflussung von Motorik und Sensorik“, Einfluss auf die Befunde hat. Es könnte auch überprüft werden, ob eine Art „Placebo-Anzug“, der die sensorischen/motorischen Systeme nicht beeinflusst, aber als „Altersanzug“ benannt wird zu gleichen Ergebnissen führen würde.

Gleichzeitig zeigen die Ergebnisse von Studie 3 (Vieweg & Schaefer, 2020), dass das Ausmaß der Leistungseinschränkung bei jungen Erwachsenen von den einzelnen Komponenten des Anzuges und der jeweiligen Aufgabe entscheidend mitbestimmt wird. Die Ergebnisse von Scherf (2014) bestätigen, dass Anzüge mit unterschiedlichen Modulen und damit induzierten Schweregraden zu unterschiedlichen Leistungseinbußen bei jungen Erwachsenen führen. In der Studie zeigten junge Montagearbeiter aus der Autoindustrie vergleichbare Montageleistungen zu älteren Arbeitern (ohne Anzug), wenn sie den am wenigsten einschränkenden Anzug trugen. Das geplante Studiendesign von Timm et al. (2021) enthält zwei verschiedene Varianten des Altersanzuges GERT. Die Autoren gehen davon aus, dass sich die beiden Varianten „GERT mit vollem Gewicht“ und „GERT mit geringem Gewicht“ sowohl unterschiedlich auf die Leistung in zwei verschiedenen körperlichen Aktivitätsaufgaben auswirken als auch auf die Erwartungshaltungen der Probanden.

Es ist deshalb notwendig, die Effekte der Komponenten des GERT-Anzuges systematisch und einzeln zu testen. So könnte man beispielsweise den Purdue Pegboard-Test (Lafayette Instrument, 2015), ein Test, der ein- und bimanuelle Finger- und Handfertigkeit und somit feinmotorische Fähigkeiten testet, einmal nur mit der Brille, einmal nur mit den Gummihandschuhen und einmal sowohl mit der Brille als auch den Handschuhen des Altersanzuges durchführen. Dies würde zu einer Differenzierung der gefundenen starken Einschränkungen der Feinmotorik in der Studie von Vieweg & Schaefer (2020) führen und verdeutlichen, ob diese eher auf die visuelle oder auf die taktile Einschränkung der Finger(-kuppen) zurückzuführen sind. Wahrscheinlich ist auch, dass erst die Kombination aus beiden Faktoren zu den massiven Leistungsrückgängen führt. Ein Vergleich mit älteren Probanden würde hier Aufschluss über die tatsächlichen Leistungseinbußen geben. Weiterhin könnten auch die Gewichte, beispielsweise die 10 kg-Gewichtsweste, angepasst werden. Möglich wäre, die Gewichte entsprechend dem Körpergewicht der Probanden abzustimmen. Da sich weibliche und männliche Probanden in ihrem Gewicht meist (deutlich) unterscheiden, könnte man so einen objektiveren Vergleich schaffen und auch die Leistungsrückgänge genauer mit entsprechenden Normwerten vergleichen. Letztendlich unterscheiden sich auch die verfügbaren Alterssimulationsanzüge in ihren Komponenten und so sind die gefundenen Einschränkungen in Abhängigkeit vom Anzug zu betrachten und demnach nicht generalisierbar.

Die Frage, inwiefern sich das Tragen eines Altersanzuges auf das motorische Lernen bei jungen Erwachsenen auswirkt, sollte zukünftig mit Aufgaben getestet werden, die mehrgelenkige Bewegungen oder Bewegungen im Raum sowie komplexere Sequenzen (z. B. mehr Elemente oder längere Dauer) beinhalten. Die Ausführung derartiger Aufgaben erhöht nicht nur die motorischen Freiheitsgrade, sondern auch die Anforderungen an zentrale Verarbeitungsprozesse. Die Untersuchung des expliziten motorischen Sequenzlernens könnte weiterhin den Einfluss der Alterssimulation auf kognitive Prozesse beim motorischen Lernen, wie die Verarbeitung des visuell-räumlichen Arbeitsgedächtnisses oder der exekutiven Funktionen (z. B. Aktualisierung [Updating]), beleuchten. Beispielsweise könnte man Licht-Sensoren (z. B. FITLIGHT-System; VISUS, 2022) an einer Wand anbringen und diese über Aufleuchten (visuelle Stimuli) eine 10- oder 12-elementige Sequenz anzeigen lassen. Durch das Berühren des leuchtenden Sensors wird dieser ausgeschaltet und ein neuer Sensor kann aufleuchten. Die jungen Probanden (mit und ohne Anzug) und die älteren Erwachsenen ohne Anzug würden aufgefordert, den aktuell aufleuchtenden Sensor so schnell wie möglich zu deaktivieren. Die körperliche Beanspruchung kann gesteigert werden, indem die Sensoren (weit) auseinander platziert und die Probanden instruiert werden, die Sensoren so schnell wie möglich zu deaktivieren. Beim Tragen des kompletten GERT-Anzuges sollten sich vor allem die Gewichte und die Überziehschuhe, mit Gleichgewichtsschwierigkeiten bei Richtungswechseln, bemerkbar machen. Die Leistung (Bewegungszeit) der Jungen im Anzug sollte signifikant schlechter sein als die Leistung derjenigen ohne Anzug. Es ist anzunehmen, dass die Zeit der Jungen im Anzug zwischen der Zeit derjenigen ohne Anzug und der Zeit der älteren Erwachsenen liegen würde.

Letzten Endes bleibt die entscheidende Frage: Wie (gut) kann Altern bzw. Altsein simuliert werden? Im Vergleich zu älteren Erwachsenen, die keinen Alterssimulationsanzug tragen, zeigten junge Probanden im Anzug (deutlich) bessere Leistungen beim Balancieren eines Würfelturms auf einem Tablett und beim Übersteigen eines Hindernisses (Studie 2). Auch beim Erlernen einer einfachen motorischen Sequenzaufgabe übertrafen die jungen im Anzug die älteren Probanden deutlich (Studie 1). Beim Ausführen verschiedener groß- und feinmotorischer Aufgaben schränkte der Anzug die Leistungen der jungen Erwachsenen in einem Maße ein, das vergleichbar war mit Normwerten von etwa 55-85-Jährigen in den respektiven Tests (Studie 3). Es kann argumentiert werden, dass die peripheren Einschränkungen des Anzugs bei jungen Menschen eine Simulation typischer altersbedingter Leistungsreduktionen in motorischen Fähigkeiten wie Kraft, Ausdauer und Beweglichkeit ermöglichen. Neuronale Mechanismen, die mit zunehmendem Alter immer häufiger auftreten (z. B. weniger effiziente interhemisphärische Integration, verringerte intrakortikale Hemmung bzw. mehr neuronale Aktivierung), können jedoch nicht simuliert werden, genauso wie altersbedingte Einschränkungen in Informationsverarbeitungsprozessen (z. B. der Verarbeitungsgeschwindigkeit und -menge). Auch strukturelle Veränderungen (z. B. kleinere und langsamere Skelettmuskelfasern oder Volumenabnahme des Gehirns), die zu funktionelle Einschränkungen führen, können nicht nachgeahmt werden. Trotzdem kann das Tragen des Anzuges die visuelle oder auditive Wahrnehmung junger Menschen beeinflussen. In diesem Zusammenhang stehen auch die Anpassungen im Verhalten und in den Einschätzungen junger Probanden im Anzug von Studie 1 (Vieweg et al., 2022) und 3 (Vieweg & Schaefer, 2020). Ohne regressive, interne Veränderungsprozesse anstoßen zu müssen, kann die motorische Leistung und die Selbstwahrnehmung junger Erwachsener durch den Alterssimulationsanzug GERT beeinflusst und teilweise auf das Niveau älterer Erwachsener gebracht werden. Demnach müssen keine erkrankten, älteren Personen getestet werden, um zum Beispiel Wissen über chronische Krankheiten (Hör- und Sehminderung oder Diabetes mellitus) zu generieren. Es können gesunde, junge Probanden in speziell entwickelten Anzügen getestet werden, ohne ältere Probanden eventuellen Beeinträchtigungen oder Gefährdungen durch die Testung auszusetzen, die gesundheitlich und ethisch nicht vertretbar wären.

4.2 Altersbedingte Unterschiede im Motorischen Lernen

Beim Ausführen und Erlernen von Bewegungen gilt es, zum richtigen Zeitpunkt die richtige Bewegungsaktion auf einen sensorischen Reiz der Umwelt oder des Körpers auszuwählen und die Aktion möglichst präzise auszuführen. Informationsverarbeitungsprozesse sind daher zu jedem Zeitpunkt von Bewegungsausführungen von großer Bedeutung. Zu Beginn gilt es, ein Bewegungsziel festzulegen, die aufgabenrelevanten Reize zu verarbeiten, einen Bewegungsplan zu erstellen und diesen an die Peripherie zu den beteiligten Effektoren zu senden. Schlussendlich sollte der Bewegungsplan, der zum Beispiel Informationen zur relativen (zeitlichen) Abfolge der Einzelbewegungen oder dem relativen Krafteinsatz beinhaltet, möglichst genau umgesetzt werden. Es gibt eine breite wissenschaftliche Evidenz dafür, dass altersbedingt sowohl zentrale Verarbeitungsprozesse langsamer und weniger umfangreich werden (Salthouse, 1996, 2000; Shea et al., 2019) als auch kognitive Funktionen, wie das Gedächtnis oder exekutive Funktionen (Diamond, 2013; S.-C. Li et al., 2004; S.-C. Li & Dinse, 2002; Rönnlund et al., 2005), Leistungseinbußen erfahren. Obwohl Vertreter der Motorikforschung einen Zusammenhang zwischen kognitiven Fähigkeiten und dem motorischen Lernen oft postuliert haben (Cai et al., 2014; Voelcker-Rehage, 2008), wurde der direkte Zusammenhang bei jungen und älteren Erwachsenen bis jetzt selten untersucht (Bo et al., 2009; Bo & Seidler, 2009). Die Ergebnisse von Bo und Kollegen (2009) zeigten, dass die Abnahme des visuell-räumlichen Arbeitsgedächtnisses die altersbedingten Unterschiede zwischen jungen und alten

Erwachsenen im expliziten motorischen Sequenzlernen teilweise erklärten. Die eigenen Studien 1 und 4 der Autorin (Vieweg et al., 2020, 2022) liefern ergänzende Evidenz dafür, dass es bei älteren Erwachsenen einen direkten Zusammenhang zwischen den nachlassenden kognitiven Fähigkeiten und schlechteren motorischen Lernleistungen gibt. In Beitrag 4 wurde der Zusammenhang eines globalen kognitiven Maßes, dem MoCA Test, und der Lernleistung junger und älterer Erwachsener in einer einfachen motorischen Sequenzaufgabe verdeutlicht. Zusätzlich wurde die Dauer der Bewegungsausführung (1300/2000 ms) hinsichtlich ihres Effekts auf die motorische Lernleistung der jungen und älteren Probanden untersucht. Für die älteren Erwachsenen zeigte sich, dass ein schlechter MoCA Punktewert (niedriger Wert) mit einer schlechten motorischen Lernleistung (hoher Fehlerwert, RMSE) kovariiert. Der Punktewert des MoCA Tests gibt Auskunft darüber, wie gut die kognitiven Leistungen sind (zusammengefasst über verschiedene Domänen: Aufmerksamkeit und Konzentration, exekutive Funktionen, Gedächtnis, Sprache, visuell-konstruktive Fähigkeiten, konzeptionelles Denken, Berechnungen und Orientierung). Hinsichtlich des Erlernens des zeitlich-räumlichen Zielmusters konnten die älteren Probanden nicht von der reduzierten Zeitbeschränkung (2000 ms-Bedingung) profitieren. Beide Erkenntnisse können durchaus im Zusammenhang betrachtet werden. Die älteren Erwachsenen konnten die längere Bewegungszeit nicht nutzen, um mit Hilfe von Rückmeldeprozessen schon während der Ausführung Korrekturen zu planen und durchzuführen (closed loop-Prozesse). Zurückgeführt werden kann dies auf ihre verlangsamte Verarbeitungsgeschwindigkeit oder auf Beeinträchtigungen in kognitiven Funktionen, wie dem Arbeitsgedächtnis oder den exekutiven Funktionen (z. B. Aktualisierung). Denkbar ist jedoch auch, dass das visuelle Feedback (Cursor) welches während der Ausführung zur Verfügung stand, nicht ausreichend für die älteren Probanden war, um es in die Korrekturprozesse miteinbinden zu können. Wahrscheinlich ist, dass für die älteren Erwachsenen die Zeit nicht ausreichend war, um das (wenige) visuelle Feedback während der Bewegungsausführung zu verarbeiten. Des Weiteren scheint auch die 2000 ms-Bedingung in der Ausführung noch zu schnell für die älteren Erwachsenen zu sein. Künftige Studien könnten deshalb die Bewegungszeit der verwendeten motorischen Sequenzaufgabe weiter anpassen. Vorstellbar wäre, den Älteren deutlich mehr Zeit zur Ausführung der Bewegung zu geben (closed loop-Prozesse fördern) oder die Zeitspanne vor der Bewegungsausführung zu verlängern, damit Senioren die erforderlichen Informationen sammeln und verarbeiten können (pre planning unterstützen). Alternativ könnte auch das Ausmaß an visueller Rückmeldung während der Ausführung für die älteren Probanden erhöht werden. Eine weitere Möglichkeit wäre, dass nicht nur der Cursor, sondern auch das Zielmuster während der Bewegungsausführung gezeigt werden.

Die Ergebnisse von Beitrag 1 (Vieweg et al., 2022) weisen darauf hin, dass während der Ausführung der gewählten Aufgabe die visuelle Rückmeldung eine untergeordnete Rolle beim Erlernen der Sequenz spielte. Obwohl die jungen Erwachsenen in ihrer Weitsicht durch die Brille des Altersanzuges (GERT) stark eingeschränkt waren, konnten sie diese Einschränkung innerhalb der ersten Versuche kompensieren. Die Ergebnisse sprechen eher dafür, dass junge Erwachsene mit und ohne Alterssimulationsanzug beim Ausführen der motorischen Sequenz in 1300 ms ihre Korrekturprozesse anhand interner propriozeptiver Rückmeldungen gestaltet haben. Auf diese internalen Prozesse der Jungen hatte das Tragen des Altersanzuges keinen Einfluss. Weiterhin zeigen die Ergebnisse der Kognitionstests der jungen Probanden im Anzug, dass dieser keinen Einfluss auf zentrale Informationsverarbeitungsprozesse (wie die Geschwindigkeit) der jungen Erwachsenen hatte. Die marginal schlechteren Leistungen in den Kognitionstests der Jungen im Anzug sind zum Beispiel durch Einschränkungen der visuellen Wahrnehmung beim Tragen der Alterssimulationsbrille zu erklären.

Die Frage, die letzten Endes bleibt, ist folgende: Worauf sind die Verschlechterungen der motorischen Lernleistungen bei älteren Erwachsenen zurückzuführen? Die Heterogenität des Alterungsprozesses lässt erahnen, dass es auf diese Frage keine einzelne Antwort geben kann. Dennoch gibt es die Möglichkeit, sich den Antworten von zwei Perspektiven her zu nähern. Zum einen ist es denkbar, dass die Alterung des Gehirns als generelle Ursache einen Einfluss auf die motorischen Lernleistungen der älteren Erwachsenen haben kann (common cause-Theorie, siehe Ghisletta & Lindenberger, 2005; Lindenberger & Baltes, 1994, 1997; Lindenberger & Ghisletta, 2009). Forschungsergebnisse aus dem Bereich der vorausschauenden motorischen Planung weisen darauf hin, dass die motorische Planungsleistung bei älteren Menschen ab 70 Jahren drastisch abnimmt (Wunsch et al., 2017). Es wird postuliert, dass antizipatorische motorische Planungsfähigkeiten bei älteren Menschen stark von kognitiven Kontrollprozessen, wie der Verarbeitungsgeschwindigkeit, Reaktionsplanung und der kognitiven Flexibilität, beeinflusst werden (Stöckel et al., 2017). Beeinträchtigungen zentraler Prozesse, wie der Informationsverarbeitung von räumlichen Positionen von Zielen oder der Bildung von Repräsentationen und Bewegungskommandos, führen auch beim Erlernen von Bewegungssequenzen zu Leistungseinbußen. Sind Aufmerksamkeitsprozesse oder zum Beispiel die Kapazität des (visuellen) Arbeitsgedächtnisses begrenzt, wirkt sich dies sowohl auf die Selektion von Informationen als auch auf die Kontrolle von Bewegungen aus. Einschränkungen auf der Verhaltensebene können über Zusammenhänge zwischen kognitiven und motorischen (Lern-)Leistungen erklärt oder über bildgebende Verfahren (z. B. funktionelle Magnetresonanztomographie) veranschaulicht werden. Denkbar wäre auch, die hier skizzierte motorische Sequenzlernaufgabe anzuwenden und mittels der Elektroenzephalografie (EEG) die Hirnaktivitäten zu messen und darzustellen. Die gemessenen Änderungen in der Aktivierung des Gehirns könnten Rückschlüsse zu Unterschieden in der Informationsverarbeitung zwischen jungen und älteren Erwachsenen ermöglichen. Diese können als Gründe für die unterschiedlichen Verhaltensweisen von Jung und Alt gesehen werden.

Andererseits ist es vorstellbar, dass Veränderungen und Einschränkungen in der Körperperipherie das Erlernen motorischer (Sequenz-) Bewegungen bei älteren Probanden direkt beeinträchtigen. Beispielsweise können Bewegungskommandos an entsprechender Stelle nicht richtig umgesetzt werden, wenn die zeitliche Reihenfolge und/oder die Geschwindigkeit der muskulären Ansteuerung fehlerhaft sind. Eine akkurate Bewegungsausführung ist so nicht möglich und zeigt sich bei älteren Probanden in einer beeinträchtigten Verhaltensleistung. Mit Hilfe der Elektromyographie (EMG) könnten nicht nur Unterschiede in der elektrischen Muskelaktivität beim motorischen Lernen zwischen jungen und älteren Menschen weiter untersucht werden, sondern auch mögliche muskuläre Kompensationsmechanismen (z. B. frühere oder gesteigerte Aktivierung) bei jungen Erwachsenen, die während der Bewegungsausführung einen Alterssimulationsanzug tragen. Ein Vergleich zwischen der muskulären Aktivität von jungen Erwachsenen im Altersanzug und älteren Erwachsenen ohne Anzug kann Aufschluss über die Wirkung der Anzugskomponenten (z. B. zusätzliche Gewichte & Bandagen) auf Muskelfunktionen liefern. Der direkte Vergleich ermöglicht es, Aussagen über die Ähnlichkeit der muskulären Aktivierung und Involvierung zu treffen. Weiterhin könnten auch Effekte einzelner Komponenten auf die muskuläre Aktivierung genauer untersucht und unabhängig voneinander betrachtet werden.

Letzten Endes spielen bei älteren Menschen sowohl Beeinträchtigungen kognitiver Prozesse als auch sensorische Einschränkungen in der Peripherie eine bedeutende Rolle beim motorischen Lernen. Je nach Art und Anforderungen der gewählten motorischen Aufgabe wird neben den zentralen Verarbeitungsprozessen der Bewegungsausführung eine handlungsleitende Rolle zugeschrieben. Schließlich ist ein Beleg für die common cause-Hypothese keine Widerlegung der specific cause-Hypothese, da sich die Hypothesen in ihren Annahmen nicht gegenseitig ausschließen. Eine umfassende Berücksichtigung kognitiver und sensomotorischer Alterungsprozesse muss demnach sowohl domainspezifische Faktoren als auch eine gemeinsame Ursache für die altersbedingt schlechteren motorischen (Lern-)Leistungen einbeziehen.

5 Fazit

Die vorliegende Arbeit soll ein differenziertes Bild hinsichtlich möglicher Ursachen für Leistungsunterschiede zwischen jungen und älteren Erwachsenen in verschiedenen Domänen (Motorik, Kognition, Sensorik, Selbstwahrnehmung und Selbsteinschätzung) aufzeigen. Dabei sollte die Verwendung eines Alterssimulationsanzuges (GERT) Aufschluss darüber liefern, wie stark die hervorgerufenen körperlichen Einschränkungen (z. B. des Sehens, der Kraft und der Beweglichkeit) die Leistungen und Entscheidungen junger Erwachsener in verschiedenen Aufgabenkontexten beeinflussen. Zusätzlich wurde der Frage nachgegangen, ob die durch das Tragen des Anzuges veränderten Leistungen und Entscheidungen der jungen Erwachsenen vergleichbar sind mit den Leistungen und Entscheidungen älterer Erwachsener.

Beitrag 3 (Vieweg & Schaefer, 2020) zeigt, dass das Tragen des Altersanzuges bei jungen Erwachsenen zu (enormen) Leistungseinbußen in kognitiven und motorischen Maßen führte und auch ihre emotionale und körperliche Selbstwahrnehmung negativ beeinflusste. Die Leistungen der jungen Erwachsenen im Anzug waren vergleichbar mit Normwerten von ca. 55-85-Jährigen in den respektiven grob- und feinmotorischen Tests.

Auch Beitrag 2 (Schaefer et al., 2022) zeigt, dass die motorischen Leistungen von jungen Erwachsenen in zwei verschiedenen Aufgaben (Tablett-Tragen und Übersteigen) durch das Tragen des Anzuges reduziert wurden. Durch den Anzug reduzierten sich ebenfalls die kognitiven und visuellen Leistungen sowie die Körperwahrnehmung der jungen Erwachsenen. Weiterhin zeigte sich, dass sich die Wahl einer angemessenen Aufgabenschwierigkeit zwischen jungen Erwachsenen im und ohne Anzug in Abhängigkeit von der Art der motorischen Aufgabe unterschied. Bei der Übersteige-Aufgabe trafen junge Erwachsene im Anzug konservativere Entscheidungen, beim Tablett-Tragen unterschieden sich die gewählten Aufgabenschwierigkeiten zwischen den jungen Erwachsenen-Gruppen nicht. Junge Erwachsene im Anzug zeigten beim Tablett-Tragen bessere Leistungen als ältere Erwachsene. Interessanterweise trafen junge Erwachsene im Anzug konservativere Entscheidungen beim Tablett-Tragen als die älteren Probanden. Bei der Übersteige-Aufgabe hingegen unterschieden sich die Leistungen der älteren und der jungen Erwachsenen im Anzug nicht voneinander. Die älteren Probanden wählten hier jedoch hinsichtlich der Aufgabenschwierigkeit einen Sicherheitspuffer von fast 10% im Gegensatz zu den jungen Probanden im Anzug.

In Beitrag 1 (Vieweg et al., 2022) konnten beim Erlernen einer einfachen motorischen Sequenzaufgabe keine Leistungsunterschiede zwischen jungen Erwachsenen mit und ohne Anzug festgestellt werden. Die visuelle Leistung (Fernsicht) wurde bei den jungen Erwachsenen durch das Tragen des Altersanzuges stark eingeschränkt, die kognitiven Leistungen verschlechterten sich hingegen nicht. Im Vergleich zu den älteren Probanden zeigten junge Erwachsene im Anzug bessere motorische und auch kognitive Leistungen (mit Ausnahme der

Fehler im Figural Speed-Test). Hinsichtlich ihrer visuellen Leistung unterschieden sie sich jedoch nicht von den Älteren.

Die heterogenen Ergebnisse der eigenen Studien (Beiträge 1 - 3) zeigen, dass das Ausmaß der Leistungseinbußen in den unterschiedlichen Domänen und auch die Beeinflussung der Entscheidungen junger Erwachsener durch den Anzug maßgeblich von der durchzuführenden Aufgabe abhängen. So werden beispielsweise die Leistungen im Digit Symbol Substitution-Test, welcher mit der Wahrnehmungs- und Verarbeitungsgeschwindigkeit überwiegend kognitive Funktionen misst, auch durch sensomotorische Aspekte mitbestimmt. Es ist daher anzunehmen, dass die Leistungseinbußen aufgrund des Anzugs hauptsächlich durch sensomotorische Aspekte, wie Veränderungen der Sehschärfe und der Feinmotorik der Finger, verursacht wurden und nicht durch einen direkten Einfluss auf die neuronale Integrität des Gehirns. Bezüglich der motorischen Leistungen wirkte sich der Altersanzug bei jungen Erwachsenen eher bei koordinativ/konditionell fordernden, aber auch bei feinmotorischen Bewegungen negativ aus. In diesen Fällen waren die Leistungen junger Erwachsener im Anzug vergleichbar mit den Leistungen älterer Probanden bzw. mit Normwerten von ca. 55-85-Jährigen in den respektiven grob- und feinmotorischen Tests (Beitrag 2 & 3). Bei Aufgaben, die in ihrer Durchführung ein Risiko beinhalten (Übersteige-Aufgabe: Sturzrisiko durch Gleichgewichtsverlust beim Überqueren der Latte), führte das Tragen des Anzuges bei jungen Erwachsenen nicht nur zu schlechteren Leistungen, sondern auch zu konservativeren Entscheidungen hinsichtlich der gewählten Aufgaben-Schwierigkeit (Beitrag 2). Die jungen Erwachsenen wurden demnach vorsichtiger in ihren strategischen Entscheidungen. Einhergehend mit der Bedeutung der Aufgabencharakteristik veranschaulichen die Ergebnisse auch, dass bestimmte Leistungseinbußen bei jungen Erwachsenen durch spezifische Einschränkungen des Altersanzugs hervorgerufen werden. So zeigten junge Erwachsene im Anzug vergleichbare oder gar schlechtere visuelle Leistungen in der Fernsicht (Beitrag 1 & 2), die eindeutig auf die Einschränkungen der Brille zurückzuführen sind. Im Sinne der specific cause-Hypothese zeigt dieses Beispiel, dass altersbedingte Verschlechterungen auf degenerative Veränderungen einzelner sensorischer Endorgane (z. B. der Augen) und somit auch auf unabhängige domainspezifische Faktoren zurückgeführt werden können. In diesen Fällen wiegt die Einschränkung eines Endorgans – des Auges – schwerer als die Beeinträchtigung durch eine zentrale Größe (z. B. des Gehirns, siehe commom cause-Hypothese).

Ein weiterer Schwerpunkt der Arbeit liegt auf den möglichen Ursachen für altersbedingte Leistungsunterschiede beim motorischen Lernen. Dabei lag der Fokus auf der Bedeutung der Interaktion von nachlassenden kognitiven und motorischen Lernleistungen bei älteren Menschen. Die ermittelten signifikanten Korrelationen zwischen den kognitiven Maßen und der motorischen Lernleistung in den Beiträgen 1 (Vieweg et al., 2022) und 4 (Vieweg et al., 2020) verdeutlichen, dass ein Teil der Varianz der motorischen Lerndefizite bei älteren

Erwachsenen durch reduzierte kognitive Leistungen erklärt werden kann. Dies konnte sowohl für ein globales Kognitionsmaß (MoCA, Beitrag 4), als auch für die Geschwindigkeit zentraler Prozesse der Informationsverarbeitung gezeigt werden (DS & FS, Beitrag 1). Nach der common cause-Hypothese (Ghisletta & Lindenberger, 2005; Lindenberger & Baltes, 1994, 1997; Lindenberger & Ghisletta, 2009) lässt sich der Zusammenhang zwischen dem kognitiven Altern und dem Erlernen sequenzieller Bewegungen auf einen gemeinsamen Ursprung zurückführen, nämlich die Alterung des Gehirns. Durch die altersbedingten biologischen Veränderungen des Gehirns und die Beeinträchtigung der Integrität des zentralen Nervensystems kommt es zu vielfältigen Einschränkungen der Informationsverarbeitung, die nicht nur die kognitiven Leistungen beeinträchtigen, sondern auch mit sensorischen und sensomotorischen Leistungen bei älteren Erwachsenen kovariieren. So findet sich im Alter eine beträchtliche gemeinsame Varianz zwischen nachlassenden kognitiven, sensorischen und (senso-)motorischen Funktionen. Im Rahmen der Informationsverarbeitung können Kognition und Sinneseindrücke nicht isoliert voneinander betrachtet werden, sie bilden vielmehr ein integriertes System, in dem verschiedene Prozesse untrennbar miteinander verbunden sind. Beim motorischen Lernen wirkt sich eine beeinträchtigte Informationsverarbeitung sowohl auf die Selektion von notwendigen Informationen als auch auf die Kontrolle von Bewegungen aus. Die Beeinträchtigung zentraler Verarbeitungsprozesse, wie sie mit dem Älterwerden einhergehen, können jedoch nicht simuliert werden. Dies unterstreichen auch die Ergebnisse der jungen Probanden im Altersanzug aus Beitrag 1 (Vieweg et al., 2022). Die Ergebnisse bestätigen gleichzeitig die Bedeutsamkeit zentraler Informationsverarbeitung beim motorischen Sequenzlernen.

Altern ist ein Prozess, der sich über Jahrzehnte streckt und überwiegend durch langsame, degenerative Veränderungen geprägt ist. Die Gesamtheit dieser Veränderungsprozesse ist nicht nur durch ihre Komplexität (unterschiedliche Systeme und Ebenen sind beteiligt), sondern auch durch eine hohe Heterogenität hinsichtlich des zeitlichen Verlaufs und des Ausmaßes an Veränderungen gekennzeichnet. In diesem Kontext ist der Einsatz von Alterssimulationsanzügen der Versuch, einige der geläufigen altersbedingten körperlichen Veränderungen zu simulieren und jungen Menschen so ein Gefühl für „das Altsein“ zu vermitteln. Lässt man sich auf die Idee ein, dass spezielle Brillen, Kopfhörer, Bandagen und zusätzliche Gewichte Einschränkungen der sensorischen und motorischen Fähigkeiten ähnlich denen im fortgeschrittenen Alter bewirken, so können Alterssimulationsanzüge zur Debatte um allgemeine oder spezifische Ursachen für kognitive und (senso-)motorische Verschlechterungen im Alter beitragen. Die peripheren Einschränkungen des Anzuges ermöglichen Einblicke in eine veränderte Sinneswahrnehmung und ihre Bedeutung für Entscheidungen und Leistungen in überwiegend kognitiven oder motorischen (Lern-)Aufgaben. Die Annahme, dass Leistungsbeeinträchtigungen im Alter ausschließlich auf eine einzelne, spezifische Ursache zurückzuführen sind, ist heute jedoch nicht mehr haltbar. Vielmehr scheint eine Verflechtung multipler Faktoren wahrscheinlich, die die Leistungsminderungen im fortgeschrittenen Alter begründen.

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Anhang

Anhang 1: Beitrag 1

Vieweg, J., Panzer, S., & Schaefer, S. (2022). Effects of age simulation and age on motor sequence learning: Interaction of age-related cognitive and motor decline. *Human Movement Science, 87,* 103025. Advance online publication. https://doi.org/10.1016/j.humov.2022.103025

Effects of age simulation and age on motor sequence learning:

Interaction of age-related cognitive and motor decline

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Abstract

Aging is known to lead to decrements in sensory and cognitive functioning and motor performance. The purpose of the present experiment was twofold: a) We assessed the influence of wearing an age simulation suit on motor sequence learning, cognitive speed tasks and far visual acuity in healthy, younger adults. b) We evaluated the interaction of cognitive aging and declining motor sequence learning in older adults. In a between-subjects design we tested 11 younger adults (M_{age} = 23.6 years) without the age suit, 12 younger adults wearing the age suit (M_{age} = 23.2 years), and 23 older adults (M_{age} = 72.6 years). All participants learned a simple, spatial-temporal movement sequence on two consecutive days, and we assessed perceptual processing speed (Digit Symbol Substitution test and Figural Speed test) and far visual acuity. Wearing an age simulation suit neither affected the learning of the simple motor sequence nor the performance at the cognitive speed tasks in younger adults. However, far visual acuity suffered from wearing the suit. Younger adults with and without the suit showed better motor sequence learning compared to older adults. The significant correlations between the cognitive speed tests and the motor learning performance in older adults indicated that cognitive aging partially explains some of the variance in age-related motor learning deficits.

Keywords: Simulation Suit, Motor Learning, Information Processing, Aging

1. Introduction

As part of our everyday life sequential movements are ubiquitous. For example, when preparing a cup of coffee or entering the code of your cash card, single actions must be performed in a certain temporal order to achieve the tasks' goal. Especially for older adults executing movement sequences can be challenging. Motor sequence learning in younger and older adults has been widely investigated, and age-related performance decrements have been demonstrated in a variety of tasks over the last decades (Goggin & Meeuwsen, 1992; Panzer et al., 2014; Seidler, 2006; Vieweg et al., 2020; see Voelcker-Rehage, 2008 for a review). For example, Verwey (2010) used a discrete sequence production task to investigate chunking in sequence learning in younger and older adults. In this task, participants practiced a three and six-element sequence by pressing the spatially corresponding key to a visual stimulus presented on the screen, as quickly as possible. The results showed that the slower sequence production of the elderly was associated to the limited motor chunk use compared to younger adults. Shea et al. (2006) used dynamic multi-element movement sequences (repeated vs. random sequence) to investigate age-related effects in motor learning. Younger and older participants moved a lever as quickly and smoothly as possible to visually presented targets, by extension-flexion movements of the forearm. Younger adults performed the repeated sequence substantially faster than older adults during practice (acquisition) and the retention test (learning). The aforementioned tasks illustrate that the limited ability to perform and learn motor sequences at an advanced age applies to a large number of motor tasks that differ in their characteristics, such as movement duration, movement degrees of freedom, feedback conditions, and control processes (Curran, 1997; Kovacs et al., 2009; Krakauer et al., 2019). In general, movement execution becomes slower, more variable, and less accurate with increasing age (Panzer et al., 2011; Pohl et al., 1996; Vieweg et al., 2020). The reasons for these age-related regressive changes in motor performances can be divided - maybe oversimplified - into underlying decrements in "peripheral processes" and "central mechanisms".

Bodily changes, like reductions in muscle strength and decreased flexibility of joints (Holland et al., 2002; Hunter et al., 2016), as well as impaired sensory acuity for vision, hearing and tactile perception, are well documented for old age (Amaied et al., 2015; Campos et al., 2018; Roberts & Allen, 2016; Schieber, 2006). On the neuromuscular level, factors as sarcopenia which is defined as age-associated loss of muscle mass, muscle strength and muscle function (Cruz-Jentoft et al., 2010), as well as age-related changes in motor unit morphology and its neural inputs (e.g., slower and more variable contractile velocity, increased fatigability, reduced and more variable synaptic inputs) contribute to the decrements in older adults' motor performance (for reviews, see Hunter et al., 2016; Kuehn et al., 2018).

Using an age simulation suit, which simulates at least some of the peripheral limitations of old age, is one possibility to gain more insight into the differences between younger and older adults in motor sequence learning. Age simulation suits are claimed to offer a whole-body experience of multiple physical constraints of healthy aging, such as loss of sensory perception and reduced strength and flexibility. The detrimental effects of wearing an age suit on younger adults' motor and physical performances have been shown in different tasks (Lauenroth et al., 2017; Lavallière et al., 2017; Scherf, 2014; Vieweg & Schaefer, 2020). Lauenroth et al. (2017) investigated the effect of an age suit on several gait parameters (velocity, step length, step time and base width) and found a reduction for step length and velocity similar to an age increase of 20 to 25 years for the younger participants wearing the suit, in comparison to older adults. Vieweg and Schaefer (2020) examined the effects of the model "GERT" (GERonTologic simulator) developed by Moll (2021), on different gross motor (strength, flexibility, aerobic endurance, and balance/agility) and fine motor tasks (Pegboard tasks and shirt buttoning), as well as on a cognitive speed task (Digit Symbol Substitution test) and self-perception in healthy, younger adults. The results indicated strong performance decrements in fine- and gross motor functioning in younger adults comparable to the level of mid-50- to 85-year-olds, based on the respective age norms of the tests. Additionally, the suit led to severe declines in processing speed and self-perception (mood and physical state) in younger adults. In summary, previous studies showed (strong) detrimental effects of wearing an age simulation suit on gait and motor performances in younger adults. However, it is unclear whether – and to which extent – the peripheral constraints of an age suit lead to declines when learning a sequential motor task in younger adults. To the best of our knowledge, currently no studies exist that have examined the influence of an age simulation suit on motor sequence learning. In brief, the age simulation suit allows for an investigation of more peripheral factors relative to central/cognitive factors in motor sequence learning. Further, it is still unknown how the impaired processing speed due to the peripheral suit limitations affects motor sequence learning in younger adults.

There is strong evidence for age-related declines in cognitive functions, such as memory, reasoning, and spatial ability (Li & Dinse, 2002, Li et al., 2004; Rönnlund et al., 2005; Verhaeghen & Salthouse, 1997). Psychological theories attributed the decline of older adults' performance in several cognitive tasks to a central cause, namely brain aging. The common cause theory of cognitive aging postulates an increasing association between cognition and sensory acuity (e.g., vision, hearing) with advanced age, which can be primarily attributed to brain aging, as a general mechanism (Baltes & Lindenberger; 1997; Ghisletta & Lindenberger, 2005; Lindenberger & Ghisletta, 2009). The interrelatedness of declining cognitive functions and motor performance in older adults is also of interest to theorists of motor learning (see Cai et al., 2014, and Ren et al., 2013 for reviews). Impaired performances of older adults in motor sequence learning tasks are associated to age-related decline in cognitive functioning at times. Performance declines of older adults in motor learning are sometimes studied in direct relation to age-related declines in cognitive functioning (Bo et al., 2009; Vieweg et al., 2020). Bo et al. (2009) observed that visuospatial working memory declines partially explain age-related differences in explicit motor sequence learning. Vieweg and colleagues (2020) found that the cognitive status of older adults, measured by a dementia-screening tool including measures of attention, working-memory, executive functioning and visual-spatial ability, correlates with impaired motor sequence learning in older adults. In general, cognitive functions such as memory, attention and reasoning, are subject to central information processing. A central process in this respect is the speed at which information is processed. The speed of information processing is known to deteriorate with increased age and is seen as a major contributor to age-related decline in many areas of cognition (Salthouse, 1996; 2000; Shea et al., 2019). Salthouse (1996) hypothesized that the limited time mechanism, meaning that relevant cognitive operations are executed too slowly to be successfully completed in a certain time window, and the simultaneity mechanism, defined by the slow processing of a reduced amount of simultaneously available information, are responsible for the relation between speed and cognition in old age. Besides, increased information processing speed also plays an important role in motor sequence learning. As a result, movement sequence learning requires the perception of the spatial positions of the targets before, during and/or after movement execution, and response selection and response execution in a narrow time window. However, the direct relationship between declines in processing speed and age-related decrements in motor sequence learning has rarely been investigated.

By using an age simulation suit, which simulates multiple physical constraints of healthy aging, we wanted to investigate how the peripheral limitations of the suit influence performance in motor sequence learning. For the motor task, we used a simple spatial-temporal sequence performed by extension-flexion movements of the forearm in a given time window. Previous findings on this task indicate that older adults produced the movement sequence less accurately and in a less harmonic motion than younger adults (Panzer et al., 2014; Vieweg et al., 2020). Concerning age simulation, recent results of Vieweg and Schaefer (2020) indicate that wearing an age simulation suit reduces information processing speed in younger adults. Since the current study aims to assess the interrelatedness of cognition and motor sequence learning, we investigated the relationship of impaired processing speed and motor sequence learning, due to age simulation and old age. We included a classic paper-and-pencil measure of processing speed (Digit Symbol Substitution test, Wechsler, 1981), and a computerized choice reaction time task (Figural Speed test, Schmiedek et al., 2010). We also assessed far visual acuity, by using an eye chart (Landolt-C-chart, Precision Vision, 2021), since decreases in visual acuity contribute to the sensory processing difficulties in older adults. Impaired sensation-perception may in part account for the general slowing in processing speed in older adults (Shea et al., 2019).

The purpose of the present study was twofold: (a) To investigate how wearing an age simulation suit affects motor sequence learning in younger adults. We used a simple spatial-temporal sequence to compare motor sequence learning in younger adults, with and without wearing an age simulation suit, and older adults. We also investigated (perceptual) processing speed and far visual acuity in younger adults, with and without the age suit, and in older adults. (b) To evaluate the interrelatedness of cognition and motor sequence learning across age, by correlating measures of the cognitive speed tasks and the retention performance of a motor sequence learning task, in younger and older adults.

In general, compared to younger adults not wearing the suit, we expected older adults to show decreased performance in the motor sequence learning task, as well as in the cognitive speed tasks and in visual acuity. Based on the results of Vieweg and Schaefer (2020) we predicted that wearing an age simulation suit negatively affects motor sequence learning, perceptual processing speed and far visual acuity in younger adults, compared to younger adults not wearing the suit. Additionally, we assumed that performance in the retention test of the motor sequence learning task would be related to performance in the cognitive speed tasks. Further, we predicted that processing speed in older adults covaries with motor sequence learning.

2. Method

2.1 Participants

Younger adults ($N = 23$, 20 - 32 years of age; $M_{age} = 23.4$, $SD_{age} = 3.4$) and older adults ($N = 23$, 65 - 82 years of age; $M_{age} = 72.6$, $SD_{age} = 4.6$) participated in the experiment. All participants had no history of neurologic disease, stroke, musculoskeletal dysfunctions, or color blindness and had normal or corrected-to-normal vision. Handedness was determined by the Edinburgh Handedness Inventory (Oldfield, 1971) prior to the experiment. According to a moderate selection criterion of the laterality quotient LQ > 48, all participants were determined as right-hand dominant. Note that the participant groups did not differ in their laterality quotient according to the Edinburgh Handedness Inventory (younger adults with suit, $M_{Oldfield\ LQ} = 84.6$, $SD_{Oldfield\ LQ} = 17.3$; younger adults without suit, $M_{Oldfield\ LQ} = 87.8$, $SD_{Oldfield\ LQ} = 14.7$; older adults, $M_{Oldfield\ LQ} = 94.2$, $SD_{Oldfield\ LQ} = 11.1$). This is supported by the nonsignificant main effect of group in the respective ANOVA, $F(2, 42) = 2.10$, $p = .135$. Younger adults were undergraduate sport students at the university and took part for course credit. All older adults were physically active and received compensation for travel expenses (7.50 € per session) for their participation. Participants' informed consent was obtained prior to participation in the experiment. The study was approved by the Ethics committee of the Faculty of Empirical Social Science at the Saarland University.

2.2 Age Simulation Suit

The age simulation suit GERT (Moll, 2021), which is designed to simulate the consequences of physical and sensory aging on multiple dimensions, was used. Wearing this full body suit reduces sensory acuity in terms of vision, hearing and tactile perception. The colored glasses narrow the field of vision, change color perception, and create a blurry image. Hearing is affected by the earmuffs, especially for higher tone frequencies. The tactile perception of the finger and fingertips is impaired by wearing disposable plastic gloves. A neck ruff leads to restricted agility of the head, and bandages on wrists, elbows and knees reduce the flexibility and range of motion of these joints. Agility and grip ability of the fingers are impaired by wearing plastic gloves and fingerless leather gloves. Note that the leather gloves only partially cover the fingers and do not interfere with the reduced tactile perception simulated by the plastic gloves worn under the leather. Additional weights, 1.5 kg on each wrist, 2.3 kg on each ankle, and a 10 kg upper-body-vest, should lead to a decrease in whole-body strength and coordination abilities. Impaired balancing ability and an unsteady gait are intended by wearing overshoes, with a 1.5 cm thick, soft foam sole (see Figure 1). The weight vest itself is meant to simulate postural weakness (flexion of the spine and tilting of the pelvis), as well as higher physical load and decreasing strength in the upper body. The interaction of separate components should mimic the impaired sensorimotor skills of old age (Moll, 2021).

2.3 Motor Sequence Learning Task: Apparatus

The apparatus consisted of a horizontal lever, supported at the proximal end by a vertical axle that turned almost frictionless in a ball-bearing support. The lever was fixed on the right side of a table allowing the lever to move in the horizontal plane over the table. A vertical handle was fixed near the distal end of the lever. The handle's position could be adjusted so that the participant's elbow could be aligned with the axis of rotation when the handle is gripped. A potentiometer was attached to the lower end of the axis to record the position of the lever, and the output was sampled at 1000 Hz, and stored on a computer for later analysis. A wooden board was placed over the table to prevent participants from seeing the lever and their arm.

A video projector (temporal resolution 100 Hz; spatial resolution 1152 x 854 pixel), located behind the participant was used to display the target pattern, the cursor and feedback of movement execution on the wall facing the participant. Feedback was provided by superimposing the target pattern over the sequence pattern produced by the participant, and by providing the root mean square error, representing the measure of error. The root mean square error, indicates the difference between the target trajectory and the produced trajectory by the lever/limb system, was presented on top of the superimposed pattern (see Figure 2). Participants were told to attempt to reduce the error value from trial to trial. Participants were seated at about 2 meters from the wall, and a 1.28 x 1.28 m image was projected on that wall.

2.4 Experimental Groups, Task and Procedure

2.4.1 *Motor Sequence Learning Task*

Younger adults were randomly assigned to one of two practice conditions, one performing the sequence pattern while wearing the age suit ($n = 12$) and one without the suit ($n = 11$). Older adults ($n = 23$) only performed the sequence without wearing the suit. The sample size was chosen following Vieweg et al. (2020), who tested a comparable number of participants per age group with a similar sequence learning task to our task, and performed correlational analysis as well. They found large effects in the performance measures between younger and older adults and a significant correlation between motor learning performance and the cognitive status for older adults. Note that the inventor of the GERT-suit (Moll, 2021) states that wearing all components causes a decline of sensorimotor functioning, equal to an aging of 30-40 years in healthy, younger adults. Therefore, wearing the age suit would disproportionately impair the performances of older adults which is why they did not wear the suit.

All participants were informed by written and verbal instructions how to perform the task. Participants were seated on a height-adjustable chair facing the wall, with the apparatus adjusted so that each participant had a comfortable position. At the starting point, the lever was positioned so that the upper-arm/forearm angle was approximately 85°. By moving the lever with their dominant right arm, the participant's task was to perform a sequence of extension–flexion movements in 1300 ms, in the horizontal plane. Participants should attempt to perform as closely as possible to the target pattern displayed in front of them on the wall. The spatial–temporal pattern was created by summing two sine waves with different amplitudes. The maximum amplitude in the target pattern was 45° from the starting point (see Figure 2). A tone indicated the participant to position their cursor in the starting point (1°×1° box), and to begin the execution when he/she felt ready. This insured that participants started from the same position (85° elbow angle) but could initiate their response when they felt ready. Note that as soon as the participant started moving from the starting point, the target pattern and the start box disappeared, and only the cursor representing the current position of the lever/arm was displayed on the wall. The participants were instructed to perform the three reversals of the sequence (changing the movement direction from extension to flexion and vice versa) as accurately as possible. Following the completion of the participants' response, feedback was provided for approximately 5 s. Data collection was started by the movement of the lever, and for each trial the potentiometer output was recorded for 2000 ms. However, only 1300 ms were used for data analysis.

Practice of the spatial-temporal pattern consisted of 11 blocks of 9 trials. Approximately 24 h following the completion of the acquisition phase, the retention test was conducted (10 trials). Note that the retention test included 10 trials to avoid warm-up decrements (Nacson & Schmidt, 1971). The retention test required the participants to produce the sequence under the same conditions they experienced during practice on day 1. Feedback was provided by superimposing the target pattern over the produced sequence pattern.

2.4.2 *Cognitive Speed Measures and Far Visual Acuity*

For evaluating perception and processing speed of the participants, the Digit Symbol Substitution test (Wechsler, 1981) and the Figural Speed test (Schmiedek et al., 2010) were used. The Digit Symbol Substitution test is a paper-and-pencil test that requires to perceive target symbols and to copy them quickly and accurately into the respective fields. Nine different abstract symbols are used for the test, corresponding to the numbers from 1 to 9. The score is the sum of correct target symbols written down in 90 s. The Digit Symbol Substitution test (DS) primarily measures processing speed (Wechsler, 1981).

The Figural Speed test is a computer-based choice reaction time task. Participants had to decide whether two three-dimensional colored objects, consisting of several connecting parts, are exactly the same or different. If different, the objects differed with respect to one part.

Responses were given trough a button-response box, by either pressing a button with the right ("same-response") or left ("different-response") index finger. Responses should be given as accurately and quickly as possible. After a familiarization phase (40 items in total), participants performed two trials of 40 items with a short break in between the trials. Outcome variables were number of errors and response times in ms, averaged over individual responses. Lower errors and faster response times represent better performance. The Figural Speed test (FS) primarily measures perceptual processing speed (Schmiedek et al., 2010).

Far visual acuity was assessed using a Landolt-C-chart (Precision Vision, 2021). The chart was attached to the wall three meters away from the participants. Participants read the opening of the "Cs" aloud for as long as they could see them. If necessary, participants wore their glasses or contact lenses under the age suit glasses. Higher far visual acuity values represent better performance (maximum value = 2.0).

The participants performed the vision test before and the Digit Symbol Substitution test and the Figural Speed test after the acquisition of the motor sequence task (Day 1). Note that younger adults performed all tasks (vision test, motor sequence learning task, Digit Symbol Substitution test and Figural Speed test), either while wearing the age simulation suit (n = 12) or without wearing the suit (n = 11). Since data collection of the current study was part of a larger project, an additional task on the influence of age and age simulation on motor task-difficulty choices was assessed in the context of the experimental session (for more information see Schaefer et al., 2022).

2.5 Data analysis and statistics

Motor performance data were analyzed using Matlab (Mathworks, Natick, MA, 2018b). To compute lever displacement, the individual trial time series were used. For noise reduction the displacement time series were filtered with a low-pass filter (2nd order dual-pass Butterworth filter) with a cutoff-frequency of 10 Hz. As an error measure the root mean square error (RMSE), which indicates the difference between the extension-flexion trajectory produced by the participant and the target pattern, was used. The RMSE values for individual trials were averaged for each participant to yield a global estimate of RMSE for each block.

The current study tested younger adults with and without wearing the age suit and older adults, in a between-subjects design. To asses acquisition performance in the motor learning task, the mean RMSEs were analyzed with a 3 (group: young no suit, young suit, older adults) x 11 (block: 1-11) mixed-design ANOVA with repeated measures on block. For retention data, the mean RMSE were analyzed with a one-way ANOVA with the factor group (3: young no suit, young suit, older adults).

Differences in Digit Symbol performance, Figural Speed performance (number of errors and response times), and far visual acuity were analyzed with a one-way ANOVA with the factor group (3: young no suit, young suit, older adults).

Pearson's product moment correlations were calculated separately for younger and older adults to identify relationships between performance in the motor sequence learning task (retention test) and the measures of the cognitive speed tasks (DS, FS: number of errors, response times). The performances of the young adult groups (with and without the suit) were pooled for the correlations when they did not differ significantly on the retention test and the cognitive measures.

For all analyses of variance (ANOVA), F values and η_p^2 for effect sizes were reported. If sphericity assumptions were violated, Greenhouse–Geisser corrections of the degrees of freedom were reported. Significant main effects were further investigated by planned t-tests for independent samples with Bonferroni corrected levels of significance to $p < .017$. For all t-tests, we present Cohen's d effect sizes. The alpha level used to interpret statistical significance was $p < .05$. Analyses were computed with SPSS for Windows version 27.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1 Motor Sequence Learning

Figure 3 displays the RMSE results of the groups for the acquisition phase (Day 1) and the retention test (Day 2).

3.1.1 *Acquisition*

The analysis of the RMSEs indicated significant main effects of block, $F(4.96, 213.19) = 51.95$, $p < .001$, $\eta_p^2 = .55$, and group, $F(2, 43) = 28.00$, $p < .001$, $\eta_p^2 = .57$. The interaction of block and group, $F(9.92, 213.19) = .82$, $p = .611$, did not reach significance. The RMSE decreased during practice for younger and older adults. Descriptive data showed that older adults improved their performance by a mean decrease of -8.0° from the beginning (Block 1) to the end of acquisition (Block 11). Younger adults with the age suit (mean decrease of -9.1°) and without the age suit (mean decrease of -5.9°) also decreased their errors during acquisition. The main effect of group indicated that older adults showed larger RMSEs compared to younger adults in the suit, $t(32.64) = -6.76$, $p < .001$, $d = -2.41$, and without the suit, $t(32) = -5.66$, $p < .001$, $d = -2.08$. There were no differences between the two young adult groups, $t(21) = .32$, $p = .749$. They differed mainly in their performances on Block 1. However, this difference on Block 1 did not reach significance, $t(21) = 1.92$, $p = .069$.

3.1.2 *Retention Test*

The analysis of the RMSE detected a significant main effect of group, $F(2, 43) = 35.67$, $p < .001$, $\eta_p^2 = .62$. Younger adults with the suit, $t(32.43) = -8.12$, $p < .001$, $d = -2.89$, and without wearing the age suit, $t(30.29) = -6.93$, $p < .001$, $d = -2.54$, outperformed older adults. No differences between younger adults in the suit and younger adults without the suit were found, $t(21) = -1.12$, $p = .275$.

3.2 Cognitive Speed Measures and Visual Acuity

Figure 4 shows performances in the Digit Symbol Substitution test, the Figural Speed test and for far visual acuity.

3.2.1 *Digit Symbol Substitution Test*

The results of the DS scores indicated a significant main effect of group, $F(2, 43) = 33.46$, $p < .001$, $\eta_p^2 = .61$. The *t*-tests showed that older adults were outperformed by younger adults wearing the suit, $t(33) = 6.25$, $p < .001$, $d = 2.22$, and without wearing the suit, $t(32) = 6.34$, $p < .001$, $d = 2.33$. The DS scores of the two young adult groups did not differ, $t(21) = -.39$, $p = .702$.

3.2.2 *Figural Speed Test*

Number of Errors

For the number of errors, the main effect of group did not reach significance, $F(2, 43) = 2.46$, $p = .097$. There were no differences between the three groups in the number of errors committed.

Response Times

The analysis of the response times indicated a significant main effect of group, $F(2, 43) = 8.58$, $p < .001$, $\eta_p^2 = .29$. Younger adults with the suit and without the suit did not differ in their response times, $t(21) = .49$, $p = .629$. Younger adults in the suit, $t(33) = -2.91$, $p = .006$, $d = -1.04$, and without the suit, $t(27.85) = -4.41$, $p < .001$, $d = -1.17$, responded significantly faster than older adults.

3.2.3 *Far Visual Acuity*

For far visual acuity, the analysis detected a significant main effect of group, $F(2, 43) = 9.47$, $p < .001$, $\eta_p^2 = .31$. Younger adults differed significantly in their far visual acuity when wearing the suit ($M = 0.8$, $SD = 0.3$) compared to not wearing the suit ($M = 1.5$, $SD = 0.3$), $t(21) = -5.42$, $p < .001$, $d = -2.26$. In addition, younger adults without the suit showed significantly better far visual acuities than older adults ($M = 1.1$, $SD = 0.4$), $t(32) = 2.82$, $p = .008$, $d = 1.03$. Interestingly, younger adults with the suit did not differ in their acuity values compared to older adults, $t(33) = -1.89$, $p = .067$.

3.2.4 *Correlations: Retention Test and Measures of Cognitive Speed*

Performances in the DS (score) and the FS (response times and number of errors) did not differ significantly in the young adult groups (no suit vs. suit). Thus, the RMSE of the retention tests and the DS scores, as well as the number of errors and the response times of the FS, were pooled for the younger adults before computing the correlations.

For younger participants, neither the DS score (r = -.35, p = .098) nor the number of errors (r = .24, p = .267) and response times (r = -.09, p = .696) of the FS correlated significantly with their performance in the retention test (RMSE).

Older adults' performance in the retention test exhibited significant correlations with the cognitive speed tests. A strong negative correlation was found for older participants' RMSE and their DS score, r = -.53, p = .009. For the FS, there was a strong positive correlation with the number of errors made and the RMSE, r = .62, p = .001, but the correlation between the response times and the RMSE did not reach significance, r = -.35, p = .100. These findings indicate that in older participants, lower DS scores and higher numbers of errors in the FS co-vary with higher RMSE (see Figure 5, the respective scatterplot for the younger adults is presented as supplementary material).

4. Discussion

In the present experiment we investigated the effects of wearing an age simulation suit on motor sequence learning, cognitive speed tasks and far visual acuity. We assumed that wearing an age suit negatively affects motor sequence learning, perceptual processing speed and far visual acuity in younger adults, compared to not wearing the suit. We also predicted older adults to show performance decrements in the motor sequence learning task, as well as impaired processing speed and reduced far visual acuity, compared to younger adults. Learning a motor sequence task requires information processing about the spatial position of the targets, planning and organizing the elements in the sequence and the articulatory activities required to execute the planned action (Shea et al., 2019). Information processing, as the speed and the amount of simultaneously available information that can be processed, deteriorate with old age (Salthouse, 1996). We wanted to investigate the direct relationship between (perceptual) processing speed and motor sequence learning. We assumed that age-related slowing in processing speed co-varies with declines in motor sequence learning in older adults.

During the acquisition of the sequential motor task, all participants improved their performances. In this phase younger participants outperformed older adults, regardless of wearing or not wearing the age suit. On the retention test, older adults produced significantly higher RMSE than the younger participants. Again, the two young adult groups did not differ in their retention performance.

As expected, older adults produced larger errors in sequence execution and exhibited less sequential movement learning compared to younger adults. This finding is in line with previous movement sequence learning experiments (e.g., Panzer et al., 2014; Shea et al., 2006; Vieweg et al., 2020). The reasons for these results are varied, including for example the task characteristics. In the present study, participants had to perform the extension-flexion movement in a given time window of 1300 ms. According to the planning and control framework proposed by Glover (2004), movements of shorter durations and with fewer elements, are primarily pre-planned in timing and velocity, compared to movements of longer duration and with more elements. Based on this assumption, movements of shorter duration and with fewer elements predominantly rely primarily on preplanning, while movements of longer durations and with more elements have an initial pre-planned component after which control is gradually taken over by an online control mode and adjustments can be made “in flight” (Kovacs et al., 2010; Panzer et al., 2014). For the sequence used in this study, it appears that planning and executing of even simple sequential movements may interfere in older adults but not in younger adults. This is in line with the findings of Salthouse (1996) for older adults, that information processing cannot be successfully executed (limited time) if the results of early processing are no longer available when later processing has to be completed (simultaneity). Vieweg et al. (2020) support these findings by showing that older adults' spatial accuracy suffers at the beginning of sequence production when the pre-planning mode is primarily responsible for controlling sequence execution. Additionally, it appears that older adults had difficulties to adequately tune the muscle activation pattern needed, to perform the sequential movement as precisely as the younger participants. This is in accordance with research of pointing movements for which Dounskaia and colleagues (2005) reported that delays in the acceleration profiles in reciprocal movements are associated with difficulty to adequately tune the muscle activation pattern. It could also be that the internal proprioceptive information was not sufficient or could not be processed fast enough, by the older participants. Likewise, the spatial information during movement execution displayed only by the position of the cursor, indicating the limb/lever system, might not be sufficient external visual information for older adults to perform the movement accurately.

In contrast to our predictions, wearing an age simulation suit did not impair the learning of a simple movement sequence in younger adults. Younger adults wearing the age suit adapted within the first trials of the acquisition phase to the restrictions of the suit and showed no impairment during the following blocks, nor in the retention test on the following day. These findings can be related to the properties of the age simulation suit. The components of the age suit may limit the range of motion or reduce strength and sensory perception in younger adults (Vieweg & Schaefer, 2020). However, they may be less suitable to simulate the effects of degenerative bodily changes, as sarcopenia or a reduced number of sensory receptors. It is likely that younger adults wearing the age suit compensated for the peripheral constraints, for example the additional weight of 1.5 kg on the wrist, due to increased muscle activity. This is in line with theoretical account from Henneman (1957) that additional load (e.g., around the wrist) could provoke increased resistance in the joint, for example the elbow, that can be compensated for by increased recruitment of motor units in younger adults. Studies examining the effects of increased or decreased load on the (inter-manual) transfer of a learned movement sequence indicated that younger participants were able to effectively compensate for decreased and increased load with virtually no changes in performance characteristics (Fries et al., 2010; Muehlbauer et al., 2007). In these studies, additional loads can affect the stretch-shortening cycles in a way that individuals have problems to decrease the movement speed at the reversal points. It seems that younger adults had no difficulties in decreasing the movement speed at the reversal points.

The findings can also be related to the experimental setup and the task properties. Participants were sitting on a chair and rested their arm on a lever while performing the movement sequence. In this context, the restrictions of the lower body, with bandages around the knees, additional weights around the ankles and the overshoes, and probably even the additional weight of the upper-body vest may not exert a strong influence on younger adults' performance. Note that while executing the movement sequence the target pattern was not shown, only the cursor representing the current position of the arm/lever was displayed. Due to this, a visual comparison between the target template and the executed movement was not necessary or possible. Therefore, younger adults were able to compensate for the restrictions of the glasses in the current task. Even if the age suit had worked to its full potential, by making the younger adults 30 to 40 years older (Moll, 2021), the younger adults in this study would still have been too young on average. In future studies, the younger adults in the suit should be, on average, 35 years younger than the older adults.

As expected, the results of the vision test showed decreased performances for far visual acuity for younger adults in the age suit compared to younger adults not wearing the suit. Interestingly, the restrictions of the glasses were so severe that younger adults' vision was comparable to the values of older adults (see Figure 4). Note that even though younger adults were allowed to wear their own glasses or contact lenses under the suit glasses, the blurry image created by the suit glasses strongly affected their far visual acuity. Interestingly, the significantly reduced visual acuity did not affect sequence learning in younger adults. This could indicate that execution of the current visual-spatial sequence task does not need to be visually controlled in younger adults, at least not in a constant fashion.

In the current study, younger adults with and without the suit did not differ in their results on the cognitive speed tasks. Both tests, the Digit Symbol Substitution test and the Figural Speed test, measured processing speed, which is seen as a predominantly cognitive function (Li et al., 2004; Wechsler, 1981). Even though, wearing the suit might affect sensation-perception (i.e., visual-perception or tactile-perception), central information processing processes, as the speed with which they are carried out, are not affected. In addition, the age simulation suit cannot influence the neuronal integrity of the brain in younger adults. The Digit Symbol Substitution test results of the current study contradict those of Vieweg and Schaefer (2020). Note that Vieweg and Schaefer tested 20 younger adults in a within-subjects design. Younger participants performed the cognitive speed test (Digit Symbol Substitution test) once with and once without wearing the suit, and performances were significantly lower when wearing the suit. The current results for the younger adults not wearing the suit differ from the results of Vieweg & Schaefer (2020). The different results may be due to the smaller sample size of the current study, and the different experimental designs used. This can also apply to the results of the Figural Speed test. Retest and practice effect may have played a role in the findings of Vieweg and Schaefer (2020), as opposed to the current study. Future studies should further investigate how the age simulation suit affects sensation-perception and how this relates to younger adults' performance on cognitive speed tasks.

As predicted, younger and older adults differed in terms of their processing speed in the Digit Symbol Substitution test and the Figural Speed test. The age-associated changes in information processing are subject to a general decline in older adults when compared to younger adults (Salthouse, 2000; Shea et al., 2019). Furthermore, the impaired visual acuity may in part contribute to the general slowing in processing speed in older adults compared to younger adults. Interestingly, younger and older adults did not differ in their accuracy in the Figural Speed test. This is in line with findings that older adults emphasize more on accuracy than on speed, known as the speed-accuracy trade-off, in reaction time tasks (Heitz, 2014; Salthouse, 1979). The greater emphasis on accuracy as opposed to speed contributes to the slower performance of older adults and may partially explain some of the age differences in speed of performance between younger and older adults.

The current experiment indicated that performance in the cognitive speed tests is associated with performance in motor sequence learning in older adults, but not in younger adults. This finding is consistent with our initial hypothesis. The negative correlation between the DS score and the RMSE on the retention test suggested that older adults who processed (perceptual) information faster showed superior performance in sequence execution. Additionally, the positive correlation between the errors in the FS and the RMSE on the retention test indicated that older adults, who produced more errors in the FS also showed impaired performance in sequence execution. Our results are in line with other findings that reported that a lower level of cognitive functioning, for example in working memory, attention and executive functions, is associated with a lower level of explicit (Bo et al., 2009) and implicit motor sequence learning (Vieweg et al., 2020) in older adults. In line with the findings of Vieweg and colleagues (2020), we provide additional evidence that the learning of a simple movement sequence, where a spatial-temporal movement pattern must be performed as accurately as possible, is related to cognitive functions in older adults. We extend this finding by showing that age-related declines in central information processes, as defined by reduced (perceptual) processing speed, may be associated with age-related declines in motor sequence learning. Future research should continue to investigate these associations in younger and older adults, using larger sample sizes than the current study.

Concerning the ecological validity of age simulation studies, it should be kept in mind that wearing an age suit is a short-term intervention. It cannot be equated with the long-term aging process that older adults go through. Due to large interindividual differences in physical limitations and cognitive abilities between older adults, aging is a very idiosyncratic process. In addition, it triggers a multitude of compensatory strategies that help older adults deal with age-related decrements (Baltes & Baltes, 1990). Nevertheless, we argue that using an age simulation suit offers an attractive possibility to experimentally influence at least some of the peripheral sensory and physical losses that many older adults experience. Concerning age-related cognitive and motor decline, future research using age simulation can hopefully contribute to explore the underlying decrements in more “peripheral” and “central processes” of aging (see also the debate about “common” or “specific” causes of cognitive aging; Baltes & Lindenberger, 1997; Christensen et al., 2001; Lindenberger & Ghisletta, 2009). The restrictions of the periphery by the age simulation suit allow us to gain insights into the importance of sensorimotor perception and processing in motor learning and cognitive tasks.

In conclusion, wearing an age simulation suit did not impair the learning of a simple movement sequence in younger adults in the current design. Younger participants in the suit still outperformed older adults during the acquisition and the retention test, executing the sequential movement with fewer errors. Furthermore, wearing the age suit did not affect cognitive functioning, as related to (perceptual) processing speed, in younger adults, but it impaired far visual acuity. Younger adults’ far visual acuity in the suit was reduced to a level comparable to the visual acuity of older participants. Additionally, our results contribute to the existing literature that there is a close interaction between cognitive aging and deficits in motor learning (Cai et al., 2014; Ren et al., 2013). The covariation of the cognitive speed measures and the RMSE of the retention test suggest that central information processing partially predicts motor sequence learning in older adults. The results indicate that decreased processing speed is involved in some of the regressive changes in motor learning in old age.

Future age simulation research should test motor learning tasks involving multi-joint movements or more complex motor sequences (e.g., more elements or reversals). Performing these tasks requires to control more degrees of freedom and demands more physical and cognitive effort. The study of explicit sequence learning would also shed light on the influence of age simulation on other cognitive processes involved in motor learning, such as (visuospatial) working memory or executive functioning (e.g., updating). In consideration of the close interaction of cognitive aging and deficits in motor sequence learning, the selection of the cognitive tests should be oriented even more closely to the requirements of the motor learning task in future studies.

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Declaration of interest

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Appendix

Figure 1

Figure 2

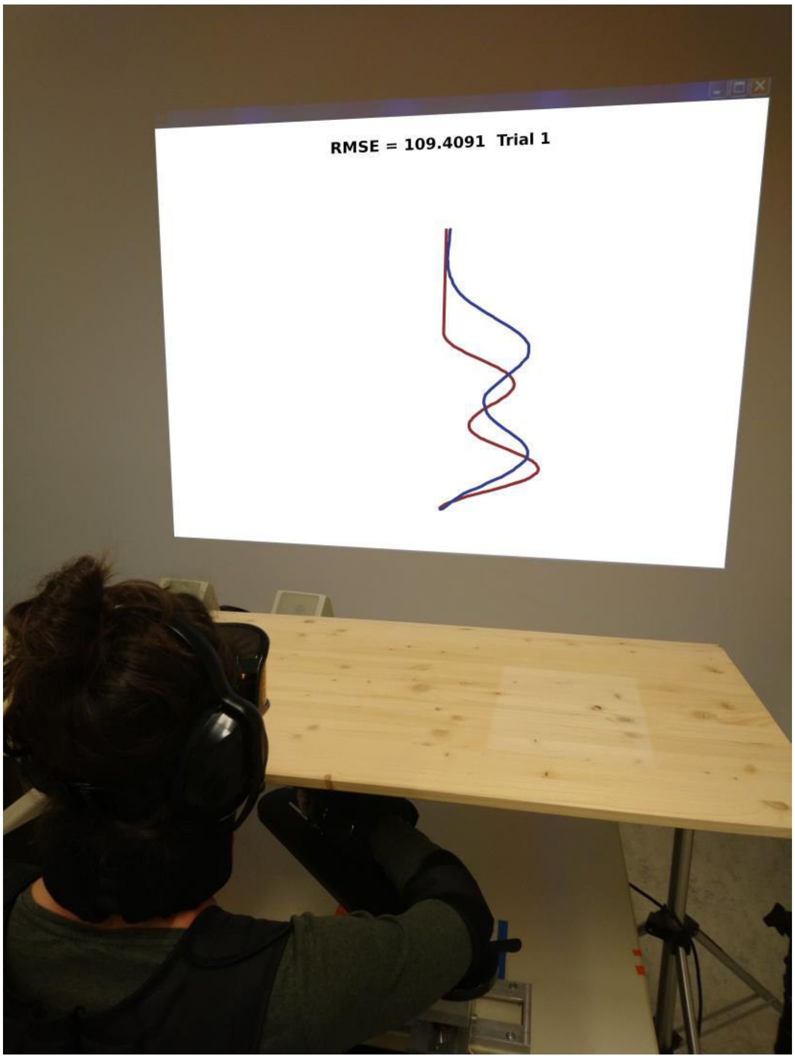
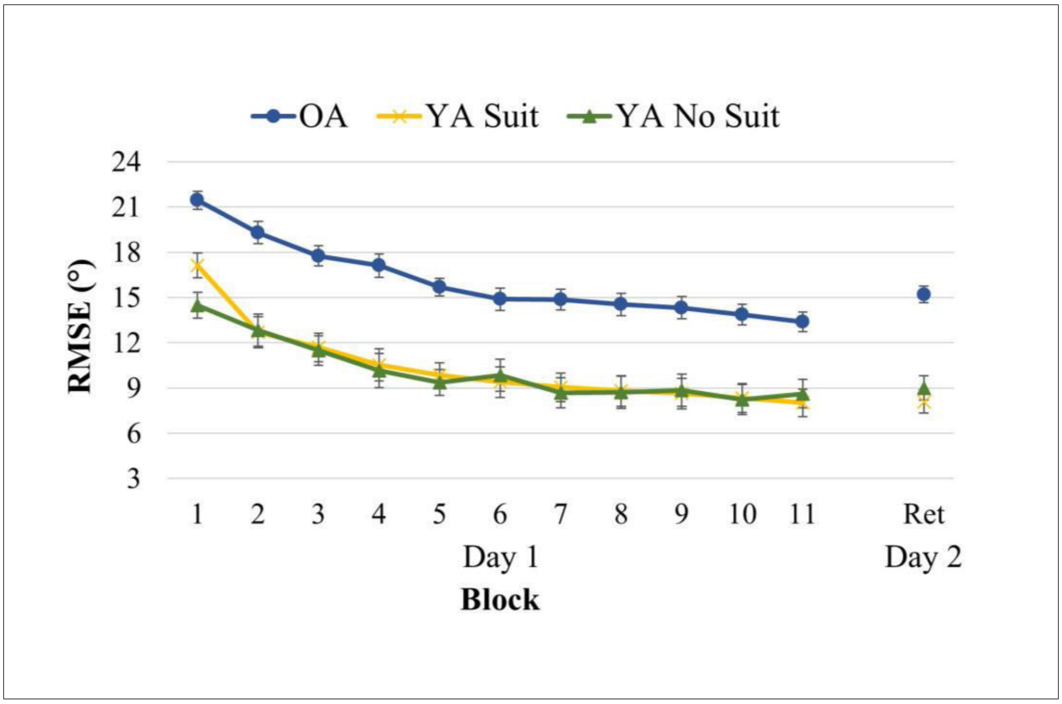
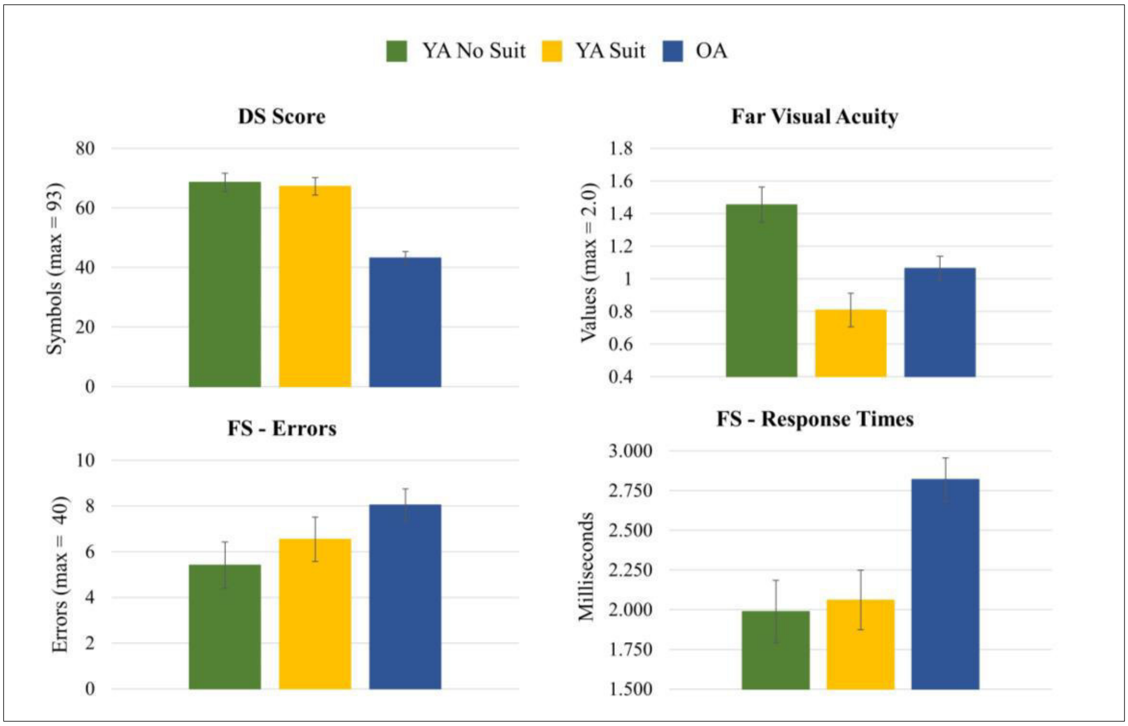


Figure 3



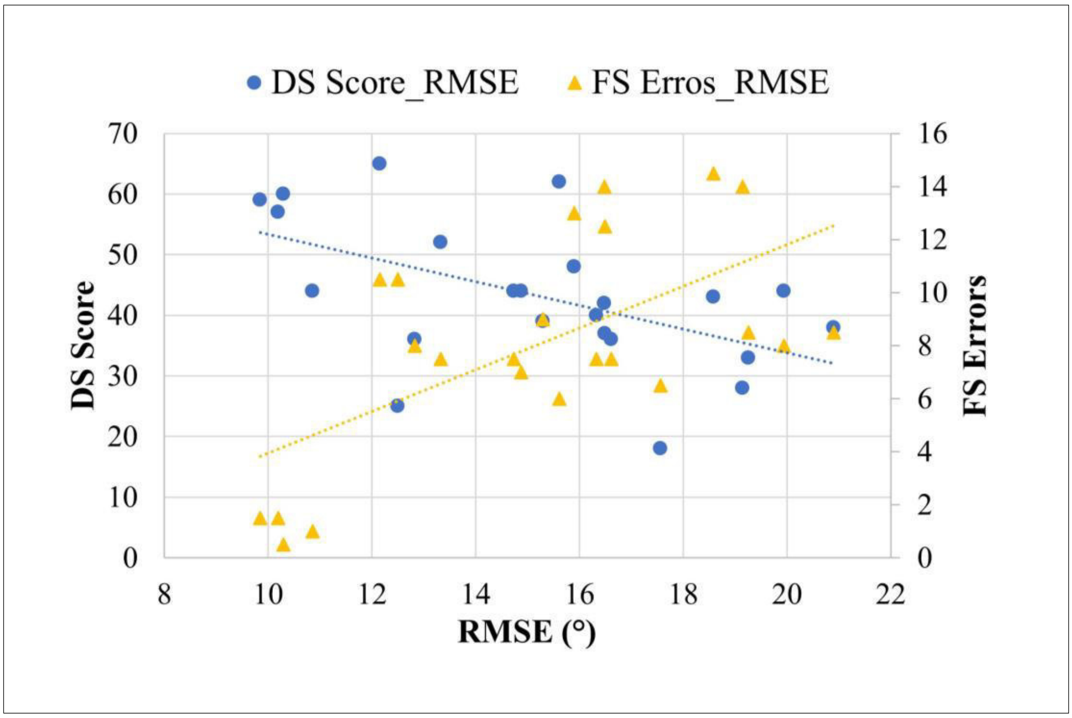
OA
YA Suit
YA No Suit
RMSE (°)
24
21
18
15
12
9
6
3
1 2 3 4 5 6 7 8 9 10 11
Ret
Day 1
Day 2
Block

Figure 4



YA No Suit
YA Suit
OA
DS Score
Symbols (max = 93)
80
60
40
20
0
Far Visual Acuity
Values (max = 2.0)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
FS - Errors
Errors (max = 40)
10
8
6
4
2
0
FS - Response Times
Milliseconds
3.000
2.750
2.500
2.250
2.000
1.750
1.500

Figure 5



DS Score_RMSE
FS Erros_RMSE
70
60
50
40
30
20
10
0
DS Score
16
14
12
10
8
6
4
2
0
FS Errors
8
10
12
14
16
18
20
22
RMSE (°)

Figure Captions

Figure 1

The Age Simulation Suit Model "GERT"

Figure 2

Illustration of the Apparatus with a Participant, Wearing the Age Simulation Suit, Sitting in Front of a Table

Note. The target sequence pattern, the produced sequence pattern and the error measure (RMSE) are projected on the wall in front of the participant. During the experiment the executive limb was covered by a wooden board.

Figure 3

Mean RMSE and Standard Error of the Means for Younger and Older Adults during Acquisition (Day 1) and the Retention Test (Day 2)

Note. Ret = Retention test. Error bars = SE mean.

Figure 4

Cognitive Speed Performances and Far Visual Acuity of the Younger and Older Adults

Note. DS = Digit Symbol Substitution test. FS = Figural Speed test. Error bars = SE mean.

Figure 5

Scatter Plot of the RMSEs and the DS Scores (Blue Dots) and the FS Errors (Yellow Triangles) of the Older Adults. The Blue Line Represents the Linear Regression Slope of the DS Scores, and the Yellow Line the Regression Slope of the FS Errors

Anhang 2: Beitrag 2

Schaefer, S., Bill, D., Hoor, M., & Vieweg, J. (2022). The influence of age and age simulation on task-difficulty choices in motor tasks. *Aging, Neuropsychology, and Cognition*, 1–26. https://doi.org/10.1080/13825585.2022.2043232

The Influence of Age and Age Simulation on Task-Difficulty Choices in Motor Tasks

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Abstract

Older adults are faced with the challenge to remain physically active, while at the same time avoiding physical risks, which could lead to falls. Having a realistic perception of one's motor abilities is an important condition for choosing a suitable level of task-difficulty. We used two different motor tasks, carrying a tray with cube-towers (study 1; n = 20 young adults; n = 20 older adults), and stepping over a crossbar (study 2; n = 23 young adults; n = 21 older adults). We assumed that older adults would show more conservative task-difficulty choices in the stepping task, which is more risky than the tray-carrying task. In addition, we investigated the effect of wearing an age simulation suit on young adults' task-difficulty choices. The suit reduces sensory input (vision, hearing, touch) as well as motor abilities (balance, flexibility, strength, and fine motor control). For the tray-carrying task of study 1, older adults were more risk-tolerant in their task-difficulty choices, leading to a higher incidence of towers collapsing as compared to young adults. When stepping over the crossbar (study 2), older adults left a larger "safety-buffer" than young adults, and chose difficulty levels that were lower in relation to their optimal performance. When wearing the age suit, young adults also adopted a more careful strategy in the stepping task. This indicates that healthy older adults' strategies take postural risks into account, and that young adults' strategy-choices can be influenced by experimentally inducing some of the sensory-motor constraints of old age.

(249 words)

Keywords: age simulation, motor performance, aging, risk taking, task-difficulty choices

The Influence of Age and Age Simulation on Task-Difficulty Choices in Motor Tasks

Aging is known to result in a variety of bodily changes that make motor performance more difficult, like reductions in vision and hearing (Roberts & Allen, 2016; Paraskevoudi et al., 2018), decreased flexibility of the joints, and reductions in muscle strength (Holland et al., 2002; Li & Dinse, 2002). These changes in the underlying perceptual and motor abilities lead to pronounced age-related declines in various motor tasks (Leversen et al., 2012). On the other hand, a physically active lifestyle has repeatedly been shown to be one of the most effective influential factors for successful aging, exerting positive influences on numerous health parameters (Hollmann et al., 2007) as well as on brain health and cognitive performances (for reviews, see Colcombe & Kramer, 2003; Erickson et al., 2015; Hertzog et al., 2009; Voss et al., 2011).

Older adults are therefore faced with the challenge to remain as physically active as possible, while at the same time avoiding physical risks. Falls are common in old age, and they can lead to severe consequences (Callisaya et al., 2012; Schillings et al., 2005; Tinetti & Kumar, 2010; Van Voast Moncada & Mire, 2017). An increase in fear of falling may also contribute to further reductions in activity levels (Boyd & Stevens, 2009; Denkinger et al., 2015; Scheffer et al., 2008). Identifying potentially dangerous situations and accurately assessing one’s own abilities are important prerequisites for optimal decisions.

Task-difficulty Choices: The Selection Margins Paradigm

The current studies create experimental situations in which participants have to choose a suitable task-difficulty level. This sheds light on their strategies: Do they over- or underestimate their abilities? Riediger et al. (2006) propose to investigate these phenomena across the lifespan. In their framework, the discrepancy between the empirically defined maximum manageable task–difficulty and the self-selected task difficulty of an individual is called “selection margin”. Progressive selection margins represent an overestimation of one’s performance, while conservative selection margins represent an underestimation. A recent set of studies (e.g., Schaefer et al., 2021) compared the selection-margin decisions of children and teenagers to those of young adults, using two different gross motor tasks (rope skipping and ball dribbling) and a fine-motor task (tracing). Younger individuals showed stronger tendencies to overestimate their motor performances. This may be due to their everyday experience of improved performances across a wide range of motor tasks, caused by practice and maturation. With increasing age, participants' selection-margin decision became more realistic.

On the other end of the lifespan, it is possible that older adults are rather pessimistic about their abilities, since they experience declines in cognitive and motor performances (Leversen et al., 2012; Li et al., 2004). However, older adults have been shown to overestimate their abilities in several cognitive tasks (Crawford & Stankov, 1996; Hansson et al., 2008; Shing et al., 2009). Overestimations have also been demonstrated for driving abilities (Wechsler et al., 2018; Wood et al., 2013) or for motor tasks. A study by Butler et al. (2015) asked older adults to walk over planks of different lengths, heights, and widths. The shortest path had the narrowest and tallest plank, and the longest path had the widest and lowest plank. Behavioral risk was defined as the probability of falling off the chosen plank. For safety reasons, participants walked over their chosen path on ground level, and not in the elevated condition. While participants with good physical abilities took slight behavioral risks, the choices of those participants with poor physical abilities were poorly calibrated to their abilities. They either took very high behavioral risks or chose the overly safe path with no risk. Behavioral risk was associated with falls during the subsequent year. The authors conclude that undue risk-taking should be taken into account when designing fall prevention programs.

Studies by Sakurai and colleagues (Sakurai et al., 2013, 2014, 2017) asked older adults to predict their stepping-over abilities. Before attempting the task, from a distance of 7 m, participants were asked to choose the height of a bar that they would be able to safely step over. They were then asked to step over this height, and their actual performance was measured. While young adults showed a tendency to under-estimate their performance, a rather high percentage of older adults (up to a third of the sample) over-estimated their performance and was not able to step over the chosen height. This tendency was stronger in older adults with an inactive lifestyle (Sakurai et al., 2014), and it was not mediated by visual height perception (Sakurai et al., 2017).

However, findings from cognitive-motor dual-tasks indicate that older adults show a “posture-first” strategy in potentially risky situations (Al-Yahya et al., 2011; Li et al., 2001; Lövdén et al., 2005; Lundin-Olsson et al., 1997; Ozdemir et al., 2016; Schaefer, 2014; Woollacott & Shumway-Cook, 2002). Li et al. (2001) asked young and older adults to walk on a narrow track while concurrently encoding word lists. Dual-task costs represent the extent to which performances are reduced in comparison to each individual’s baseline performance under single-task conditions. Older adults’ dual-task costs were much higher than young adults’ costs in the memory domain, but comparable to young adults’ costs in the walking domain. This indicates that older adults have prioritized the motor domain, which represents an adaptive strategy in the context of this study, since it reduces the risk of falling. Mamerow et al. (2016) argue that adult age differences in risk-taking may strongly depend on the characteristics of the task (see also Shao & Lee, 2014). The current studies therefore investigate whether motor tasks that differ in their risk for physical harm elicit different strategy choices in older adults.

Age Simulation

Older adults experience age-related decrements in motor and cognitive performances over the course of several decades. However, acute changes in one's physical state may also influence strategic choices. We therefore assess whether wearing an age simulation suit influences young adults' task-difficulty choices. Age simulation suits claim to offer a realistic whole-body experience of aging, by reducing physical strength, joint flexibility, and sensory perception. Age simulation suits have initially been developed to increase empathy for older people in medical training (Shore, 1976; Tullo et al., 2010). Wearing such a suit strongly decreases young adults' motor and physical performances (Lauenroth et al., 2017; Timm et al., 2021; Scherf, 2014; Schneider, 2011; Zijlstra et al., 2016). The current studies used the model GERT (GERonTologic simulator) developed by Moll (2020). A recent study tested healthy young adults with and without the GERT suit in a within –subjects design (Vieweg & Schaefer, 2020). The study reports pronounced performance declines in a variety of gross-motor tasks (measuring strength, flexibility, aerobic endurance, and balance/agility), as well as in two fine motor tasks (Purdue Pegboard Test and shirt buttoning), and in cognition measured by the Digit Symbol Substitution test (Wechsler, 1981). Based on the age norms of the respective gross- and fine-motor tests, performances of young adults wearing the suit were reduced to the level of mid-50 to 85-year olds. Wearing the suit also led to declines in perceived physical state and mood. After being tested in the suit, healthy young adults reported decreased self-perceived energy, fitness, flexibility, and health. We therefore assumed that wearing the suit decreases performances in the tray-carrying and the stepping task in the current studies.

In addition to this direct influence on performance, wearing the suit can also influence young adults' task-difficulty choices. When deciding how to confront a task, people take their acute physical state into account. For example, adding weights to participants' legs made jumpable distances seem larger (Lessard et al., 2009), or wearing a heavy backpack made people judge hills to be steeper and distances to be longer (Proffitt et al., 2003; Witt et al., 2004). We assumed that wearing an age simulation suit shifts behavioral strategies of young adults. They experience pronounced performance declines when wearing the suit, presumably reducing their performances to the level of older adults (Vieweg & Schaefer, 2020).

The Present Studies

In the current studies, we use the “selection margins” paradigm to assess participants’ tendencies for over- or underestimations of their motor performances. Since the strategies may be influenced by the physical risk involved in a task, we use two different motor tasks: Carrying a tray with a tower of objects (study 1), and stepping over a crossbar (study 2). Different groups of young and older adults are recruited for the two studies. While carrying the tray does not involve a risk of falling, stepping over the crossbar does. Maximum-manageable task difficulties are assessed repeatedly at the beginning and the end of the experimental session. In the middle part, participants are asked to choose a suitable task-difficulty level. Participants can therefore base their task-difficulty choices on their own previous experience with the respective task. The paradigm “punishes” overestimations, by not awarding any points for unsuccessful trials (when the tower collapses or the crossbar falls down). We assume that young adults are well-calibrated in their task-difficulty choices. Older adults are predicted to show a higher tendency to overestimate their ability in the tray-carrying task, but to be more careful than young adults in the crossbar task, since this task involves a risk of falling.

In addition, young adults of the current studies are exposed to two conditions: Performing the task without the age simulation suit, and with the suit, in counterbalanced order. Due to the awareness of acute physical limitations in the suit condition, young adults are predicted to show selection margins that are more similar to those of older adults, with more ambitious selection margins (overestimation of their abilities) in the tray-carrying task, and more conservative selection margins in the stepping task.

Study 1: Carrying a Tray

Method

Participants

Study 1 aims to detect differences between older adults and young adults in their selection margins. Since there are no published findings on age differences in selection margins yet, effect sizes are difficult to predict.

We are also interested in changes in performances and strategic choices of young adults wearing the suit compared to not wearing the suit. We assumed that the influence of this experimental manipulation is rather strong, since the study by Vieweg and Schaefer (2020) reports significant performance reductions in all measures, with large effect sizes. We conducted a Power analysis using the G*3 Power software (Faul et al., 2007) with a significance level of 0.05. The power analysis focused on the expected performance difference between the suit and the no suit condition. The analysis indicated that a large effect size of dz = 0.90 would lead to an Actual power of 0.95 with a total sample size of 19 participants.

We recruited 20 sports students (5 women, 15 men; *age range* = 21 to 29 years; M_{age} = 24.0, SD_{age} = 2.0) of Saarland University and 20 older women (*age range* = 53 to 86 years; M_{age} = 71.8, SD_{age} = 8.6), who were regularly participating in a gymnastics class for seniors. Self-reported acute orthopedic problems, pain, a dementia diagnosis, or neurological deficits that cause tremor were the exclusion criteria. Young adults outperformed older adults on the Digit Symbol Substitution test for cognitive speed (Wechsler, 1981), corresponding to published age norms ($M_{young\ adults}$ = 70.4, $SD_{young\ adults}$ = 8.6; $M_{older\ adults}$ = 36.2, $SD_{older\ adults}$ =

13.5; t (38) = 9.5; $p < .001$). All participants had normal or corrected-to-normal vision. The study was approved by the Ethics committee of Saarland University (name of project: “Studies of cognitive-motor dual-tasking and embodied cognition”, Protocol number: 17-08). Young adults took part for course credit.

Experimental Task: Carrying a Tray with Wooden Cubes

Participants were provided with an even dinner tray (32 x 26 cm). The tray had a brim of 3.5 cm, with oval openings for the hands on the left- and right-hand side. Little towers of wooden cubes (2.5 x 2.5 cm) were placed in the middle of the tray by the experimenter, with the help of a ruler. The number of cubes used to build a tower determined the difficulty of the tray-carrying task, since a taller tower is less stable and more difficult to carry. The tray was placed on a table, and had to be carried to an identical table, covering a distance of 2 meters. The tables were 74 cm high. The participants’ task was to carry the tray and cube towers without the tower collapsing. The time taken to perform the task was not recorded. No specific strategy how to carry the tray was introduced, but participants were not allowed to touch the cubes when carrying the tray.

The maximum manageable task difficulty (mmtd) was the highest number of cubes that could be carried successfully at least once in the pre- and posttest phase. The values of the pre- and posttest phase were averaged for each participant. The selection margins score was the difference between the mean mmtds and the mean task-difficulty choices of the selection phase (please see Procedure section for details).

Experimental Manipulation in Young Adults: The Age Simulation Suit

To simulate the effects of aging in young adults, participants wore an age simulation suit, the model GERT developed by Moll (2020). This suit simulates the consequences of physical aging on multiple dimensions. Sensory acuity and tactile perception are reduced, by wearing disposable plastic gloves, fingerless leather gloves, colored and blurred glasses, and earmuffs. Flexibility and range of motion of elbows, head, knees and wrists are compromised by adjusting bandages on these joints, and by wearing a neck ruff. Whole-body strength and coordination abilities are further affected by additional weights, 1.5 kg on each wrist, 2.3 kg on each ankle, and by a 10 kg upper-body-vest. Overshoes lead to decreased balancing ability and insecure standing and gait (see Figure 2; for further details see Vieweg & Schaefer, 2020).

Procedure

Young adults performed two sessions, one while wearing the suit, and one without the suit. The order of these sessions was counterbalanced across participants. Old adults only performed one session without the suit.

Pretest performances for the tray-carrying task were assessed with pre-determined difficulty levels, with two trials for each difficulty level. Each participant started with a 5-cube-tower, and continued in ascending order of difficulty up to the 15-cube-towers.

The *selection margins phase* of the study consisted of 16 trials. Participants could choose how many cubes they wanted to use for their towers. Whenever they carried the tray successfully from one table to the other, without the tower collapsing, they received the number of points corresponding to the number of cubes. However, when the tower collapsed, participants did not receive any points for the respective trial. They were instructed to choose optimal task-difficulty levels in order to maximize their score. The maximum number of points that could be achieved in the selection margins phase was 240 (16 trials with up to 15 cubes).

To arrive at a more reliable performance baseline, and to control for practice effects throughout the study, maximum manageable task difficulties were reassessed again at the end of the session. For the *posttest*, participants worked on the same pre-determined difficulty levels in ascending order as in the pretest (two trials for each level, 5 to 15 cubes).

Analyses

The current study tested young adults with and without the suit in a repeated-measures design. To assess differences between young adults with and without the suit, and performances changes from pre- to posttest, a repeated-measures ANOVA with suit condition (2: with and without the suit) and testing occasion (2: pre- and posttest) was used. Paired samples t-test were calculated to assess differences between the suit and no suit conditions for the selection margins of young adults.

To compare the pre- and posttest performances of young adults wearing the suit to those of older adults, a mixed-design ANOVA with age group (2: young adults in the suit versus old adults) as between-subjects factor and testing occasion (2: pre- and posttest) as within-subjects factor was performed. In addition, we also conducted the respective ANCOVA, controlling for the influence of gender. For the comparison of the selection margins of young adults in the suit and old adults, an independent samples t-test was used.

T-tests were also run for the number of trials in which the towers collapsed, comparing young adults with and without the suit (paired samples t-test), and young adults wearing the suit to old adults (independent samples t-test).

For all ANOVAs, F values and generalized Eta square values for effect sizes are reported (small effect $\eta^2_G = 0.02$, medium effect $\eta^2_G = 0.13$, large effect $\eta^2_G = 0.26$) . The alpha level used to interpret statistical significance was $p < .05$. For task-difficulty choices, Cronbach's Alpha (α) reliabilities are reported. Analyses were run with SPSS version 23.

< insert Table 1 about here >

Results

Performances in Pre- and Posttest

Table 1 shows the maximum performances (cubes carried successfully) in the pre- and posttest phases of the study by age group and suit condition.

For the young adults, a repeated-measures ANOVA with suit condition (2: with and without the suit) and test occasion (2: pre- and posttest) as within-subjects factors revealed a significant main effect of suit, F (1, 19) = 8.22, p = .010, η^2_G = .111, and test occasion, F (1, 19) = 8.47, p = .009, η^2_G = .081. The interaction of suit and test occasion did not reach significance, F (1, 19) = .31, p = .587, η^2_G = .002. Wearing the suit decreased performances in the young adults, and performances in the posttest were better than in the pretest.

A mixed-design ANOVA with age group (2) as between-subjects factor focusing on young adults wearing the suit versus older adults, and test occasion (2: pre- vs. posttest) as within-subjects factor revealed a significant main effect of test occasion, F (1, 38) = 16.01, p < .001, η^2_G = .075, but no interaction of group and test occasion, F (1, 38) = .07, p = .791, η^2_G = .000. The difference between young adults wearing the suit and old adults reached significance, F (1, 38) = 6.50, p = .015, η^2_G = .122, indicating that young adults wearing the suit still outperformed older adults. Since young adults performed two testing sessions, one with the suit and one without the suit, practice may have influenced these age differences. To eliminate the influence of practice, we conducted additional analyses that compared the performances of “naïve” young adults who wore the suit in their first testing session to those of old adults. These analyses are reported as supplementary material. For the current task, the main effect of group (2: old adults vs. young adults wearing the suit in their first session) did not reach significance any longer. This indicates that task practice may have influenced the performances of some young adults.

Please note that the gender composition was unequal across groups in the current study. Young adults were predominantly males (n = 15 out of 20 participants), while there were only females in the older adults’ group. To address this issue, following the suggestion of a rewiever, we conducted a mixed-design ANCOVA with age group (2) as between-subjects factor focusing on young adults wearing the suit versus older adults, and test occasion (2: pre- vs. posttest) as within-subjects factor, controlling for gender (2) as a covariate. In this analysis, the main effect of test occasion did not reach significance any more, F (1, 37) = 3.58, p = .066, η^2_G = .088. There was no interaction of age group and gender, F (1, 37) = 1.36, p = .251, η^2_G = .036, and no interaction of age group and test occasion, F (1, 37) = .54, p = .467, η^2_G = .014. The difference between males and females almost reached significance, F (1, 37) = 3.90, p = .056, η^2_G = .096, but there were no differences between young adults wearing the suit and old adults any more after controlling for gender as a covariate, F (1, 37) = .02, p = .888, η^2_G = .001.

Task-Difficulty Choices

Cronbach's Alpha reliabilities for the 16 task-difficulty choices were excellent (all αs > .97, for the entire sample of young and older adults, and for the respective subsamples of young adults without suit, young adults with suit, and older adults only). People differed reliably in their task-difficulty choices over time.

Table 1 shows that wearing the suit reduced the number of points that young adults collected over the course of the selection margins phase, t (19) = 5.17, p < .001, in comparison to young adults not wearing the suit. The differences between young adults wearing the suit and old adults also reached significance, t (38) = 2.89, p = .006.

Selection margins were calculated as the difference between the average maximum-manageable task difficulties of the pre- and posttest and the individual's task-difficulty choices. The respective values are presented in Figure 1. Negative values indicate that participants chose difficulty-levels that were lower than their best performances. A paired-samples t-test comparing the selection margins of young adults without the suit and young adults wearing the suit did not detect significant differences, t (19) = .47, p = .642. However, a t-test for independent samples detected significant differences between young adults wearing the suit and older adults, t (38) = 3.97, p < .001, with young adults keeping a larger "safety buffer" than older adults. The pattern of results remained the same when focusing on the "naïve" young adults (see supplementary material).

< insert Figure 1 about here >

If people approach the limits of their abilities, there is an increased likelihood of critical events. In the tray-carrying task, the cube-towers can collapse. Table 1 presents the number of times that this happened in each group. Cube-towers did not collapse more often in young adults when wearing the suit as compared to not wearing it, t (19) = 1.21, p = .240, but the differences between young adults in the suit and older adults reached significance, t (38) = 2.86, p = .007. However, this difference did not reach significance any more (p = .068) when the analysis focused on the "naïve" young adults (see supplementary material).

Discussion Study 1

The tray-carrying task elicited reliable performance differences between young adults with and without the suit. However, young adults wearing the suit still outperformed older adults. This advantage did not reach significance any more when only those young adults who wore the suit in the first session were included in the analysis (see supplementary material). All groups were able to improve their performances from pre- to posttest.

In the selection margins phase, all participants chose difficulty-levels that were below their optimal performances. This is a reasonable strategy. Constantly operating at one's ability limits will very likely result in a high number of trials in which the tower collapses. The current paradigm "punished" these events, by not awarding any points for such trials. Figure 1 shows that the difference between a person's maximum manageable task-difficulty and his or her task-difficulty choices in the selection-margins phase was larger in young adults as compared to older adults. Older adults made riskier choices than young adults. The fact that they also had a higher rate of zero point trials indicates that their strategy was suboptimal. The selection margins of young adults with and without the suit did not differ. Young adults quickly adapted to their reduced performance level in the age suit, and managed to adjust their task-difficulty choices accordingly.

Failures when carrying the tray resulted in the tower collapsing. In the real world, people maybe spill some drinks when carrying on overloaded tray. The adverse consequences of such an event are probably not too severe. Therefore, study 2 increased the physical risk of the task, by asking participants to step over an obstacle. In this case, an overestimation of one's abilities creates a potentially dangerous situation, which can lead to falls and injuries.

Study 2: Stepping over a Crossbar

Methods

Participants

We expected the performance differences between young and older adults, and between young adults without the suit and young adults wearing the suit to be large, again with large effect sizes.

We recruited 23 sports students (14 women, 9 men; *age range* = 20 to 32 years*;* M_{age} = 23.0, SD_{age} = 2.4) of Saarland University and 21 older adults (10 women, 11 men; *age range* = 65 to 79 years*;* M_{age} = 71.9, SD_{age} = 24.2). None of the participants of study 2 had previously participated in study 1. Self-reported acute orthopedic problems, pain, artificial joints, severe cardiovascular problems, neurological conditions, or a cancer diagnosis were the exclusion criteria. All older adults achieved a score higher than 19 ($M_{older\ adults}$ = 26.5, $SD_{older\ adults}$ = 2.9) on the Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005). Young adults outperformed older adults on the Digit Symbol Substitution test for cognitive speed (Wechsler, 1981), corresponding to published age norms (see Table 2 for *Ms* and *SDs*; *t*

(42) = 8.92; $p < .001$). Body heights did not differ significantly between young adults ($M_{young\ adults}$ = 173 cm, $SD_{young\ adults}$ = 8.1 cm) and older adults ($M_{older\ adults}$ = 169 cm, $SD_{older\ adults}$ = 7.9 cm; t (38) = 1.7; p = .096), and there were no significant differences concerning body weight ($M_{young\ adults}$ = 71.7 kg, $SD_{young\ adults}$ = 10.6 kg; $M_{older\ adults}$ = 73.6 kg, $SD_{older\ adults}$ = 11.6 kg; t (39) = 0.56; p = .580)[1]. All participants had normal or corrected-to-normal vision. The study was approved by the Ethics committee of Saarland University (name of project: "Studies of cognitive-motor dual-tasking and embodied cognition", Protocol number: 17-08). Young adults took part for course credit. Older adults received a monetary reimbursement for study participation (approximately 7.50 Euro per hour of testing).

< insert Figure 2 about here >

Experimental Task: Stepping Over a Crossbar

The motor task of the study consisted of stepping over a crossbar. Two plastic poles stood at a distance of 1.20 m. The floor was covered with gymnastic mats. The crossbar was adjusted between the two poles, by placing it on vertical wooden stoppers that could be adjusted flexibly to a specific height on the poles. The crossbar was not fixed to the poles, but placed loosely on the stoppers, such that it would fall down when being touched (similar to constructions in high jump or pole vault). The crossbar could be adjusted to different heights between 44 cm (which corresponded to 1 point) and 103 cm (= 60 points). Participants could not see the scale on the poles in the pre- and posttest, to prevent them from acquiring an exact mental representation of their stepping performance. The scale was visible in the selection margins phase, when participants were instructed to optimize their scores. At least one experimenter was constantly present while participants stepped over the bar, to support them

[1] Please note missing values for 3 (height) and 4 (weight) older adults.

in case they lost balance. Older adults were additionally secured with a safety harness that was attached to a metal construction on the ceiling to prevent falls. This decision was implemented after pilot testing one older adult who almost knocked down the whole construction. The task was to step over the crossbar without touching it. No specific instruction was given concerning suitable motor strategies, except that any type of “jumping” while crossing the bar was prohibited. Figure 2 presents a young adult in the age suit while stepping over the crossbar. The dependent variable for the obstacle task was the highest height that was successfully crossed in the pretest and the posttest phase of the study, in relation to each individual’s leg length. The average maximum heights from pre- and posttest constituted the maximum-manageable task-difficulty (mmtd) for a specific individual (see Procedure section for details). Selection margins were calculated as the differences between an individual’s mmtd and the average task-difficulty choices in the middle part of the session. All values were expressed in relation to an individual’s leg length (%).

Background Measures: Perceived Physical State, Far Visual Acuity, and Cognitive Speed

The current physical state of the participants was assessed at the beginning and end of each testing session with the Perceived Physical State (“PEPS”; Kleinert, 2006), a questionnaire of 20 adjectives representing four dimensions: physical energy (e.g., flabby, washed out), physical fitness (e.g., well trained, strong), physical flexibility (e.g., flexible, elastic), and physical health (e.g., sick, injured) (Kleinert, 2007). The perceived physical state was assessed with a six-point rating scale ranging from *not at all* (0) to *totally* (5).

Far visual acuity was assessed using a Landolt c ring chart. Participants were wearing their glasses for the test in case they had any. In addition, the Digit Symbol Substitution test for cognitive speed (Wechsler, 1981) was assessed in each session. For young adults, all background measures were assessed once with and once without wearing the age simulation suit.

Procedure

Older adults took part in one session, and young adults in two sessions, one without and one with the age suit, in counterbalanced order. At the beginning of the session, participants completed the Perceived Physical State questionnaire. Young adults in the session with the suit completed the questionnaire before putting on the suit. The testing phase started by measuring each participant's height, weight, leg length (as the vertical distance from the hip bone to the floor, without shoes), visual acuity, and Digit Symbol performance. The stepping-over task was performed with shoes. A short warm up phase, consisting of fast walking, light jogging, stretching, and squats, was administered before the stepping over phase started. For older adults, the height of the safety harness was adjusted individually.

Pretest. An adaptive procedure was used. Young adults started at 70 % of their leg length, older adults at 60 %. If participants crossed the bar successfully, the height of the bar was increased by 3 cm. If the first attempt was a failure, participants performed a second attempt at the same height. If the bar was not crossed successfully on both trials, it was lowered by 1 cm for the next trial. When participants crossed the lowered bar successfully once, or when the bar had to be lowered to a level that had already been crossed successfully on a previous trial, this height was chosen as the maximum manageable task-difficulty (mmtd) of the pretest.

Selection Phase. In the selection phase, participants were informed that they could choose the height of the bar in the upcoming 20 trials. They could see the point scale now (44 cm = 1 point; 103 cm = 60 points), and were encouraged to choose suitable task-difficulty levels. If they managed to step over the bar, they received the corresponding number of points. If the bar fell down, they did not receive any points for the respective trial. They were instructed to collect as many points as possible, and were informed that they could change the height of the bar whenever they wanted.

Posttest. The procedure was identical to the pretest, except that the starting value was 90 % of each individual's mmtd of the pretest. Participants did not see the scale any more when working on the posttest.

The entire testing phase for the stepping task lasted about 30 to 40 minutes. Since the data collection of the current study was part of a larger project, an additional task on motor learning was assessed in the context of the experimental session. At the end of the session, the Perceived Physical State questionnaire was completed again. Young adults in the "with suit" session completed the questionnaire while still wearing the suit.

Analyses

Analyses were identical to study 1. In addition, changes in perceived physical state were assessed with paired samples t-tests for each group. Differences in far visual acuity and Digit Symbol performance were assessed with paired samples t-tests comparing young adults with and without the suit, and with independent samples t-test comparing young adults wearing the suit to older adults.

Results

Performances in Pre- and Posttest

Young adults had average leg lengths of 103.6 cm (*SD* = 6.7), and older adults 97.7 cm (*SD* = 4.8). Since leg length strongly influences the step height that can be achieved, all step heights were expressed in % of each individual's leg length. Table 2 shows the maximum step heights that were achieved in the pre- and posttest phases of the study by age group and condition.

< insert Table 2 about here >

For the young adults, a repeated-measures ANOVA with suit condition (2: with and without the suit) and test occasion (2: pre- and posttest) as within-subjects factors revealed a significant main effect of suit, F (1, 22) = 11.76, p = .002, η^2_G = .046, and test occasion, F (1,

22) = 5.66, p = .026, η^2_G = .020. The interaction of suit and test occasion did not reach significance, F (1, 22) = .74, p = .400, η^2_G = .003. Wearing the suit decreased performances in the young adults, and performances in the posttest were better than in the pretest.

A mixed-design ANOVA with age group (2) as between-subjects factor focusing on young adults wearing the suit versus old adults, and test occasion (2: pre- vs. posttest) as within-subjects factor revealed a significant main effect of test occasion, F (1, 42) = 13.23, p = .001, η^2_G = .045, but no interaction of group and test occasion, F (1, 42) = .25, p = .623, η^2_G = .001. The difference between young adults wearing the suit and old adults did not reach significance, F (1, 42) = .14, p = .708, η^2_G = .003. This shows that the suit has a strong effect on the stepping performances of young adults, reducing their performance level to that of older adults when differences in leg lengths are controlled for.

The pattern of results did not change when focusing only on those young adults who performed the “with suit” condition in their first testing session (see supplementary material for details).

Task-Difficulty Choices

Cronbach’s Alpha reliabilities for the 20 task-difficulty choices were excellent (all αs > .99, for the entire sample of young and older adults, and for the respective subsamples of young adults without suit, young adults with suit, and older adults only). This indicates that people differed reliably in their task-difficulty choices over time.

Table 2 shows that young adults without the suit chose heights that corresponded to 96 % of their average pre- and posttest-performances, while older adults chose heights that were 87 % of their pre- and posttest-performances. When wearing the suit, young adults became more conservative, by choosing heights that corresponded to roughly 94 % of their average pre- and posttest-performances. Selection margins were calculated as the difference between the average maximum-manageable task difficulties of the pre- and posttest and an individual’s task-difficulty choices. They are expressed in % of a person's leg length. The respective values are presented in Figure 3.

< insert Figure 3 about here >

A paired-samples t-test comparing the selection margins of young adults without the suit and young adults wearing the suit detected significant differences, t (22) = 2.80, p = .010. When wearing the suit, young adults' task-difficulty choices became more conservative. However, a t-test for independent samples still detected significant differences between young adults wearing the suit and older adults, t (42) = 3.63, p = .001, with older adults keeping a "safety buffer" of almost 10 % of their leg lengths when choosing suitable heights to step over.

Overestimations in the stepping-task are reflected by an increased likelihood of knocking the bar down, resulting in zero points for the respective trial. Table 2 presents the number of times that this happened in each group. The bar was knocked down more often by young adults when not wearing the suit as compared to wearing it, but this difference did not reach significance, t (22) = 1.50, p = .148, and neither did the difference between young adults in the suit and older adults, t (42) = 1.27, p = .210.

There were no changes in the pattern of results for selection margins or zero-point trials when focusing on the "naïve" young adults (see supplementary material).

Perceived Physical State

Figure 4 shows how the four dimensions changed over the course of the session. The perceived physical state remained stable over the course of the session in old adults and in young adults not wearing the suit, except for an increase in flexibility and perceived health for young adults not wearing the suit. When young adults were wearing the suit, there were significant decreases in their perceived physical state in three out of four dimensions. The testing session in the suit made young participants feel less energized, less fit, and less flexible. Only their perceived health remained stable. Table 3 presents the corresponding paired samples t-tests comparing the pre- to postsession-levels for each age group and each dimension.

< insert Table 3 about here >

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Far Visual Acuity

Table 2 shows the visual acuities in the three groups. Wearing the suit led to a significant reduction in visual acuity in young adults, t (22) = 9.57, $p < .001$. Interestingly, young adults wearing the suit had lower far visual acuities than old adults, t (42) = 2.10, p = .046.

Cognitive Speed

Performances in the Digit Symbol Substitution test are presented in Table 2. Wearing the suit led to a significant performance reduction in young adults, t (22) = 3.95, p = .001, but young adults in the suit still outperformed older adults, t (42) = 7.02, $p < .001$.

Discussion Study 2

The stepping task showed pronounced differences not only in the absolute performances, but also in the selection margins of the two age groups: Older adults were more careful, showing a tendency to under-estimate their performances more than young adults. When wearing the suit, young adults became more conservative in their choices. Their selection margins were inbetween the level of older adults and young adults without the suit.

Overall, overestimations were rare in the current task, which is also reflected by a low number of trials in which the bar was knocked to the floor. The differences between young adults in the suit and old adults remained when controlling for practice effects, by only including the “naïve” young adults into the analyses.

General Discussion

For the current studies, participants were instructed to choose suitable task-difficulty levels for two different motor tasks: Carrying a tray with a tower of cubes, and stepping over a crossbar. Different subjects were recruited for the two studies. We assessed each participant’s performance level before and after the selection margins phase. In both studies, young and older adults chose difficulty-levels that did not systematically overtax their resources, but left a “safety-buffer” in their strategic decisions. This is a reasonable strategy, since the selection margins paradigm systematically punished risky decisions (i.e., overestimations of one’s abilities). No points were awarded for trials in which the tower collapsed or the bar was knocked down. Nevertheless, these incidences sometimes occurred in the current studies.

Posture-First Strategies in Older Adults

As predicted, there were reliable age differences in the performance levels of young and older adults for the two tasks, with young adults outperforming older adults. In addition, age groups differed in their task-difficulty choices, and these differences were influenced by the nature of the motor task: In study 1, when carrying the tray, older adults were more risk-tolerant in their strategic choices than young adults, resulting in a higher number of trials in which the tower collapsed. In study 2, when stepping over the crossbar, the pattern was reversed: Older adults’ strategic decisions were more conservative, leaving a larger “safety-buffer” than young adults. This strategy appears to be adaptive, since stepping over an obstacle involves a risk of falling. As an everyday analogue, the consequences of spilling your drinks when your tray is overloaded can be dealt with, but losing your balance and falling when stepping over an obstacle should be avoided, especially in old adulthood, when falls often lead to severe consequences (Tinetti & Kumar, 2010). These findings correspond to the “posture-first” principle that has often been observed in older adults in challenging cognitive-motor dual-task situations (Li et al., 2001; Lövdén et al., 2005; Lundin-Olsson et al., 1997; Schaefer, 2014; Woollacott & Shumway-Cook, 2002). Study 1 can be interpreted as a dual-task, because participants had to walk while concurrently carrying the tray. Since walking in old adulthood requires more cognitive resources (for reviews, see Beurskens & Bock, 2012; Schaefer, 2014; Woollacott & Shumway-Cook, 2002), fewer resources can be devoted to the tray-carrying task. We did not use walking speed as an outcome measure, but it is possible that older participants walked slower in order to perform the carrying-task successfully. The extent to which our tray-carrying task requires visual attention should be investigated in future research, since visual demands of the cognitive task may increase age differences in dual-task costs (Beurskens & Bock, 2013; Bock, 2008; Bock & Beurskens, 2011).

Although older participants often show “posture-first” strategies, there are situations in which older adults overestimate their abilities. In the study by Butler et al. (2015), especially those older adults with poor physical abilities showed a tendency to be poorly calibrated in their task-difficulty choices, and some of them drastically overestimated their abilities. This strategy was related to falls in the subsequent year (see also Robinovitch & Cronin, 1999, for similar findings in elderly nursing home residents). Older adults’ failures to protect their balance have also been observed in a dual-task study (Schaefer et al., 2014), indicating that task prioritization strategies can fail in very demanding dual-task situations. Future research with the selection margins paradigm may ask participants to explicitly state why they choose specific difficulty levels, for example by instructing them to think aloud. Do participants primarily focus on previous successful attempts? Do they formulate specific plans how to confront the task? Do they refer to their own capabilities? Such think-aloud protocols may shed light on cognitive processes influencing risk-taking behavior over the lifespan.

It should be kept in mind that the selection margins paradigm does not impose strict time constraints on task-difficulty choices: Participants have sufficient time to think about their options before making a choice. In real life, however, potentially risky decisions often have to be taken under time pressure, especially in older adults, who experience slowing in motor and cognitive domains (Li & Dinse, 2002; Li et al., 2004; Wilson et al., 2004). Time-pressure may increase the likelihood of miscalibrations. It is an interesting question for future research whether time-pressure leads to more conservative or more progressive selection margins, and whether age groups differ in this respect.

Older adults of the current studies represented a rather fit sample: Eligibility criteria required participants to not suffer from severe medical conditions, and to be able to perform the motor tasks successfully. Future research should shed light on situations in which older adults overestimate their abilities, and whether participants' cognitive and motor fitness or their fear of falling can predict their behavior. Such findings can increase the understanding of situations with a high risk for falls in older adults' lives, with practical implications for elderly individuals and their caregivers.

Age Simulation

The two studies also assessed whether wearing an age simulation suit influences task-difficulty choices in young adults. As in previous studies (Lauenroth et al., 2017; Scherf, 2014; Schneider, 2011; Vieweg & Schaefer, 2020), wearing the suit strongly reduced performance levels of young adults in both motor tasks. For the tray-carrying task, selection margins of young adults with and without the suit were comparable, and more conservative than in old adults. Leaving a larger "safety-buffer" in their strategic decisions enabled them to work on the task successfully. Incidences in which the tower collapsed were rare in young adults, whereas older adults' towers collapsed in almost a third of their selection margin trials. However, when only focusing on those ("naïve") young adults that were exposed to the suit in their first testing session, differences between young adults in the suit and old adults concerning the number of "failed" trails did not reach significance any more. This indicates that practice may play a role: With sufficient experience with the age simulation, participants may be able to compensate for the suit's constraints with increasing success. Future research should investigate the exact time-course of such practice effects.

For the stepping task of study 2, wearing the age simulation suit influenced the task-difficulty choices of young adults. Young adults' choices became more conservative when wearing the suit, and were inbetween the very conservative selection margins of older adults and the (relatively) more risk-tolerant selection margins of young adults without the suit. This indicates that participants adapt to a more careful strategy in motor tasks that involve a threat to balance and a risk to fall.

Wearing the suit is not like dealing with the real process of aging over several decades. Older adults have the chance to adjust to some of their ageing-related deficits by adjusting their goals (Brandtstädter & Rothermund, 2002), or by compensating for lost means to achieve their goals (Baltes & Baltes, 1990; Freund & Baltes, 2002). Young adults who are asked to wear an age suit are suddenly faced with severe constraints, but may also be able to adapt to some of these constraints rather quickly. The literature on motor recalibration indicates that changes to the perceptual-motor system are often counteracted effectively by rescaling the system (for reviews, see Brand & de Oliveira, 2017; van Andel et al., 2017). Early attempts to reduce sensory acuity of middle-aged adults via partial occlusion filters (visual input) and noise protectors (auditory input) did not lower cognitive performance levels relative to control conditions (Lindenberger et al., 2001). However, the GERT age suit used in the current studies manipulates several bodily systems simultaneously, reducing visual and auditory input, fine motor control, joint flexibility, strength and balance. A study by Vieweg and Schaefer (2020) demonstrated that wearing the suit strongly decreased performances in a variety of gross- and fine-motor tasks, and reduced young adults' performances to the level of mid-50 to 85-year olds. In the current study, visual acuities in young adults wearing the suit were even lower than the visual acuities of older adults.

Future research with more systematic manipulations of individual bodily systems is needed to assess the magnitude of individual effects. For example, is the reduction in vision (blurry glasses), or the decrease in stability (wobbly shoes), or the decrease in physical strength (weights) or joint flexibility (bandages) particularly problematic for motor performances, and how do these manipulations influence strategic task-difficulty choices? How strongly do the different systems have to be "degraded" in order to elicit performance levels that are comparable to those of older adults? Do age differences in strategic choices still appear when perceptual and motor processes have been experimentally equated? And do people find a way to compensate for some of these constraints with increasing practice?

According to the common cause hypothesis, the increased interrelatedness of sensory and cognitive performances with advancing age in old adulthood can be attributed to a common cause, namely brain aging (Anstey et al., 2003; Anstey & Smith, 1999; Baltes & Lindenberger, 1997; Ghisletta & Lindenberger, 2005; Lindenberger & Baltes, 1994; Lindenberger & Baltes, 1997; Lindenberger & Ghisletta, 2009). On the other hand, aging-related deficits in some cognitive tasks can be directly linked to changes in the underlying perceptual abilities, in the sense of a direct cause (Gilmore et al., 2006; Glass, 2007; Murphy et al., 2000; Schneider et al., 2005). Wearing an age suit influences the perceptual-motor system, but it doesn't change the neural integrity of the brain. Nevertheless, the study by Vieweg and Schaefer (2020) showed that wearing the suit reduces the performance level of young adults considerably, not only in motor tasks, but also in cognitive tasks like the Digit

Symbol Substitution test (Wechsler, 1981), a finding that has been replicated in study 2 of the current paper. Such experimental manipulations are therefore a promising avenue for future research. They can be used to assess the amount of variance in performances and strategies that can be explained by a manipulation of peripheral factors that do not influence brain health directly. Neurophysiological approaches that measure brain activation patterns could show whether wearing the suit leads to the recruitment of additional neural circuits to compensate and maintain functioning.

It is an interesting question for this research paradigm whether the observed effects are also influenced by aging stereotypes. There is a rich literature showing that aging stereotypes are prevalent (Bennett & Gaines, 2010; Levy, 2003) and can be activated automatically (Bargh et al., 2012). Aging stereotypes influence various cognitive and motor performances (Bock & Akpinar, 2016; Hausdorff et al., 1999; Hess, 2006; Hess et al., 2003; for a review, see Meisner, 2012), as well as effort expenditure and motivation (Hess et al., 2016, 2019). Usually, older adults perform worse when they are confronted with a negative aging stereotype before working on a specific task, and their performance improves when a positive aging stereotype is activated. For our studies, we introduced the suit as an "age simulation suit". In addition to pronounced decrements in performance, we also observed changes in performance-predictions, as well as decrements in perceived physical states. Young adults reported lower levels of energy, fitness, and flexibility at the end of their testing session in the suit (again replicating a previous age simulation study by Vieweg & Schaefer, 2020). There were no such changes in perceived physical state in young adults not wearing the suit, or in old adults, although they performed the same tasks. It is possible that being confronted with various sensory and motor constraints in the "aging suit" triggered negative aging stereotypes, and elicited concerns about one's own future aging process. Future research should test whether framing the suit differently (e.g. by calling it a "challenge suit" instead of an "aging suit") influences the findings, and whether the observed effects still appear when using some kind of "placebo" suit (which does not influence sensory systems, but is labeled "aging suit").

Study Limitations

The two studies have several limitations. The fact that different study samples have been tested in studies 1 and 2 reduces the generalizability of the findings. It would have been advantageous to assess performances in the same participants in the tray-carrying and stepping-over task, using a within-subjects design, to reveal the flexible adaptation of task strategies to different task demands.

In addition, contrary to our aim, we did not succeed in lowering young adults' performances in the suit to the level of older adults in the tray-carrying task. This makes a direct comparison of the selection margins decisions across the two studies difficult. Maybe wearing the suit did not make the tray-carrying task "difficult enough". The suit's components (weights, bandages, changes in sensory perception) were apparently harder to counteract in the stepping task, such that the performances of young adults in the suit and older adults did not differ any more.

Using "suit" as a within-subjects manipulation in the young adults increased statistical power. However, direct comparisons of the three groups (young without suit, young with suit, and old adults) could not be calculated. In addition, young adults performed twice as many trials as old adults, because they took part in a session with the suit and a session without the suit. They therefore had more opportunities to practice the tasks, and to find suitable strategies for the selection-margins phase. However, when comparing old adults to only those "naïve" young adults who had the "with suit" condition in their first session, there were only few minor changes in the pattern of results for study 1, and no changes for study 2 (see supplementary material).

The gender distribution was very skewed in study 1, with only 5 females and 15 males in the young adults, and females only in the old adults. Although gender effects were not of interest for the current study, this unequal gender distribution should have been avoided. When adding gender as a covariate for study 1, some of the age differences in performance were reduced. Future research should test larger samples to increase the statistical power to detect sex-based interactions.

The decision to assess maximum manageable task-difficulties for the stepping task with an adaptive procedure has the advantage to save testing time, and to avoid frustration and boredom for participants. However, it also results in possible between-person differences in the amount of practice, which can influence selection-margins. The fact that participants did not see the point scale for the pre- and posttest phase of the stepping task made it more difficult to choose suitable task-difficulty levels in the selection margins phase. Future research should consider to always use the same kind of performance feedback throughout the entire study.

For study 2, a safety harness was used in old adults only, after one old adult almost knocked down the whole construction during pilot testing. Data collection in the young adults had already progressed by then, such that we refrained from introducing the safety harness in the remaining young adults' sample. Since the safety harness may have contributed to over- or underestimations of one's abilities, future research should use the same precautionary measures across groups.

Conclusion

To conclude, our studies show that young and older adults differ in their task-difficulty choices depending on the type of motor task. When the task involves a risk of falling (stepping over a crossbar), older adults make more conservative choices, and leave a larger safety-buffer in their decisions compared to young adults. Young adults wearing an age simulation suit adopt more conservative strategies as well. Their selection margins are inbetween those of young and older adults. The pattern was reversed for a motor task that did not include a threat to one's balance (carrying a tray with towers of cubes). Our studies add to the literature on task-prioritization processes and risk-taking in old adults, indicating that healthy old adults adaptively choose suitable motor strategies to prevent physical risks. These findings should be replicated using within-subjects designs in future research. Our findings also indicate that an age simulation suit not only decreases performance levels of young adults, but also influences their strategic choices. We argue that using age simulations contributes to the debate on common- vs. specific causes of aging. In addition, the selection margins paradigm may be a useful tool to assess strategic choices over the lifespan, and under different experimental manipulations.

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Declaration of Interest

The authors have no conflict of interest to disclose.

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Table 1

Performances of Young and Older Adults in Study 1

	Young Adults Without Suit	Young Adults With Suit	Older Adults
Maximum Performance Pretest			
(nr blocks)	13.0	11.6	10.2
M	1.8	2.3	2.2
SD			
Maximum Performance Posttest			
(nr blocks)	13.9	12.6	11.2
M	1.3	1.8	1.8
SD			
Points Collected in Selection Margin Phase (sum)			
M	141.9	117.1	94.6
SD	17.8	24.2	25.1
Number of Trials with 0 Points (max = 16)			
M	2.6	3.2	5.1
SD	1.7	1.8	2.4

Table 2

Performances of Young and Older Adults in Study 2

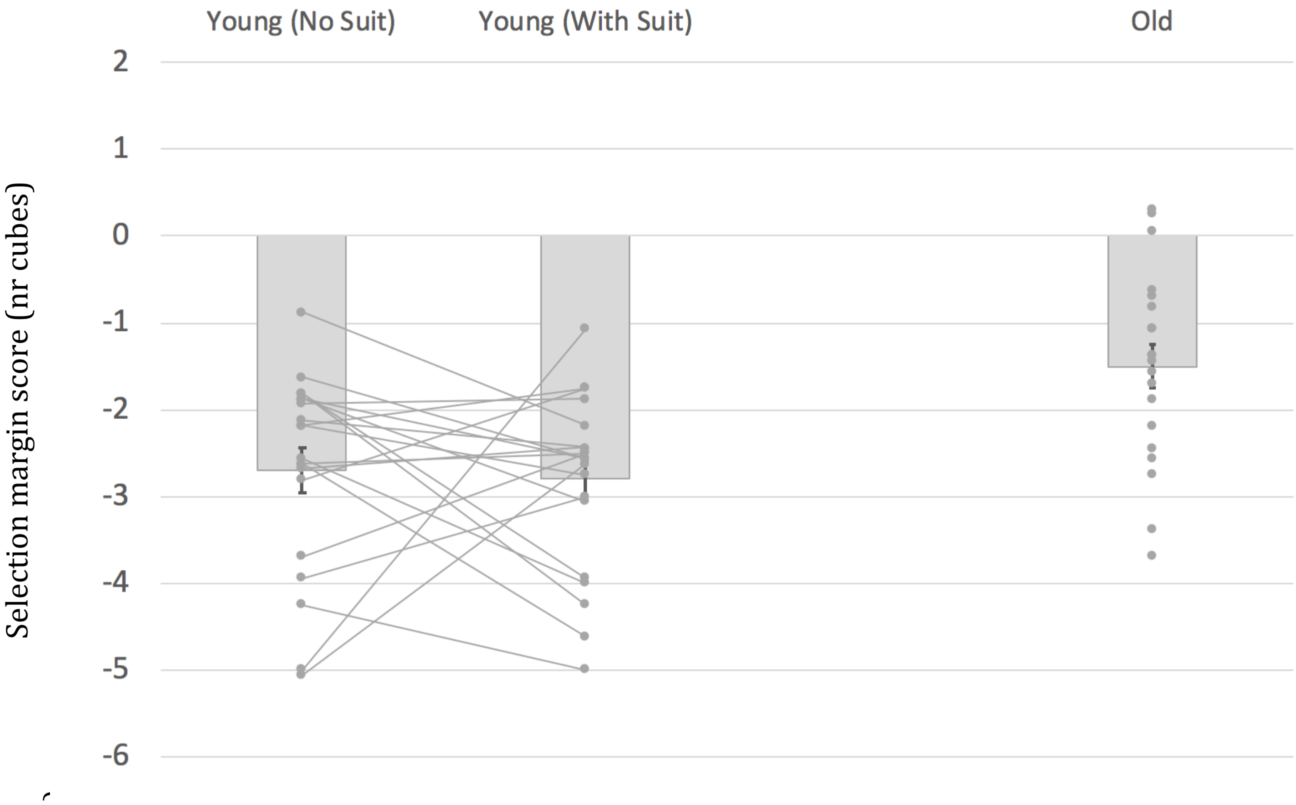
	Young Adults Without Suit	Young Adults With Suit	Older Adults
Maximum Performance Pretest (% leg length)			
M	79.1	76.8	76.1
SD	4.8	5.1	4.4
Maximum Performance Posttest (% leg length)			
M	79.9	78.5	78.3
SD	3.4	3.9	4.6
Average Chosen Height in Selection Margins Phase (% Pre- and Posttest Performance)			
M	96.0	93.8	87.4
SD	2.9	5.4	6.8
Points Collected in Selection Margin Phase (sum)			
M	577.9	542.4	405.6
SD	103.8	128.2	133.8
Number of Trials with 0 Points (max = 20)			
M	3.7	2.9	2.1
SD	2.5	1.9	2.1
Far Visual Acuity (max = 2.0)			
M	1.5	.8	1.1
SD	.3	.3	.4
Digit Symbol score			
M	71.3	66.2	44.1
SD	7.3	8.1	12.5

Table 3

Changes in Perceived Physical State throughout the Testing Session by Group

	Energy	Fitness	Flexibility	Health
Young Without Suit	t (22) = 1.11 p = .227	t (22) = .44 p = .665	t (22) = 2.98 **p = .007**	t (22) = 2.73 **p = .012**
Young With Suit	t (22) = 2.96 **p = .007**	t (21) = 2.99 **p = .007**	t (22) = 3.15 **p = .005**	t (22) = .65 p = .523
Old	t (20) = .00 p = 1.00	t (20) = 1.61 p = .123	t (20) = 1.14 p = .270	t (20) = .55 p = .589

Figure 1
Selection Margins in the Tray-Carrying Task



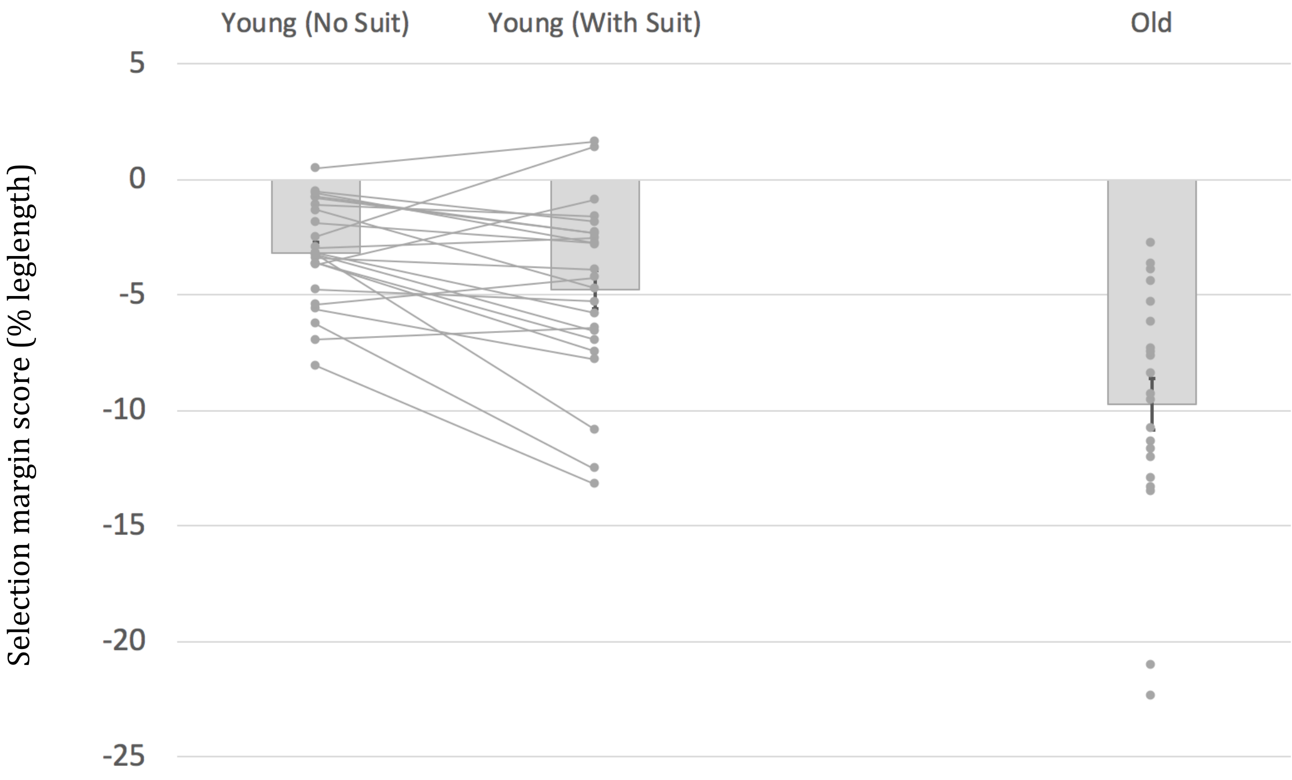
Note. Bars depict the mean selection margins of each group, points represent individual participants. Error bars = SE mean.

Figure 2

A Young Adult Stepping over the Crossbar while Wearing the Age Suit

Figure 3

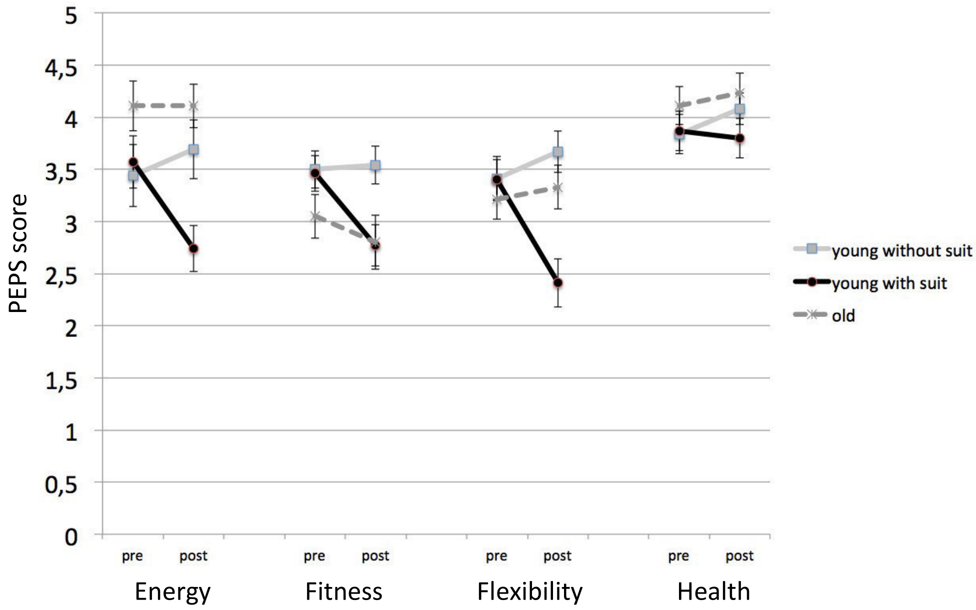
Selection Margins in the Crossbar Task



Note. Bars depict the mean selection margins of each group, points represent individual participants. Error bars = SE mean.

Figure 4

Changes in Perceived Physical State over the Course of a Testing Session



Note. Error bars = SE mean.

Figure Captions

Figure 1

Selection Margins in the Tray-Carrying Task

Figure 2

A Young Adult Stepping over the Crossbar while Wearing the Age Suit

Figure 3

Selection Margins in the Crossbar Task

Figure 4

Changes in Perceived Physical State over the Course of a Testing Session

Anhang 3: Beitrag 3

Vieweg, J. & Schaefer, S. (2020). How an age simulation suit affects motor and cognitive performance and self-perception in younger adults. *Experimental Aging Research, 46*(4), 273-290. https://doi.org/10.1080/0361073X.2020.1766299

How an Age Simulation Suit affects Motor and Cognitive Performance and Self-perception in Younger Adults

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How an Age Simulation Suit affects Motor and Cognitive Performance and Self-perception in Younger Adults

Background/Study Context: We assessed the influence of wearing an Age Simulation Suit (GERT) on gross motor, fine motor and cognitive performance in healthy young adults.

Methods: In a within-subjects design, we tested 20 young adults (M_{age} = 22.3 years) with and without the Age Simulation Suit. We assessed gross motor (Functional Fitness test) and fine motor (Purdue Pegboard test) functioning, cognitive performance (Digit Symbol Substitution test), and questionnaires on perceived physical state and mood. Gross and fine motor tests provided norms for large samples of older adults.

Results: Wearing the Age Simulation Suit leads to significant performance reductions in all task dimensions, with large effect sizes. Depending on the subtest, participants' performances were reduced to the level of mid-50- to 85-years-olds for almost all tests of gross and fine motor performance. Mood and perceived physical state also declined while wearing the suit.

Conclusion: We argue that the GERT suit offers an attractive possibility to experimentally simulate the effects of aging-related sensory and motor losses and propose future studies with this paradigm, in the context of cognitive-motor dual-tasking or motor learning.

Keywords: Age Simulation Suit, Age Comparison, Motor functioning, Cognition, Perception

Introduction

As a global development people are getting older due to better medical healthcare and changes in educational systems and working environments. The United Nations state that “virtually all countries are experiencing population ageing” (2019, p.1), which is why healthy aging is getting more into scientific focus. An aging society can be both, for example an enrichment for the economy when designing age appropriate products, or a burden to the social - and health system when dealing with the steady cognitive and motor decline of older adults. It could be helpful to enhance our perception of the difficulties older people face in their daily lives. One possibility to experience at least some of the limitations of older age is to simulate the physical constraints of aging by wearing an Age Simulation Suit. Experiencing the effects of sensory and motor declines “first hand” by wearing such a suit could increase the understanding for seniors in younger individuals.

There is plenty of scientific evidence that aging leads to decreases in sensory, motor and cognitive domains (for overviews, see Leversen, Haga, & Sigmundsson, 2012; S.-C. Li & Dinse, 2002; S.-C. Li et al., 2004; Park, Polk, Mikels, Taylor, & Marshuetz, 2001; Voelcker-Rehage, 2008). However, it is an open question whether wearing an Age Simulation Suit reduces younger adults’ performances to a similar extent.

The first attempts to simulate sensory losses that accompany the human aging process go back to the seventies (Shore, 1976). By using everyday materials, as goggles (vision), rubber gloves (tactile), ear plugs or – muffs (auditory), wheelchairs and bandages (kinesthesia), single sensory limitations were simulated to show mostly young participants what it feels like to be old.

The first full body Age Simulation Suits were invented in Germany (AgeExplorer®, Meyer-Hentschel, 2019; GERT®, Moll, 2019b), Japan (LM-60®, Koken, 2005), and in the USA (AGNES®, MIT AgeLab, 2019). These simulation suits are claimed to offer a realistic and whole-body experience to the young participants, by allowing them to simultaneously experience several consequences of physical and sensory aging (e.g., reduced strength, flexibility and sensory perception). Different sizes and individually adjustable components allow the suit to be used both by men and women, regardless of their size and weight. While all manufacturers state that their suits offer a realistic aging-experience, with components that are designed to represent the deteriorations in old age, none of them provide validation studies or empirical results to quantify their arguments. The inventor of the gerontologic simulator (GERT) states that the components of his suit cause a decline on sensorimotor functioning, equal to an aging of 30-40 years in healthy, young adults (Moll, 2019a). Given the lack of validation studies, the current paper aims to provide exact estimates of suit-induced performance changes across a variety of gross motor tasks, a fine motor task (Purdue Pegboard test), and a cognitive task (Digit Symbol Substitution test).

Addressing the needs of older adults by using Age Simulation Suits is of interest to various areas. In ergonomics, for instance, the workplace and processes should be adequate to the needs of older workers. In addition, the designed products must meet the cognitive and motor abilities of older customers. Scherf (2014) and Schneider (2011) used Age Simulation Suits for studies in the automotive industry. Schneider (2011) wanted the management and workers of an automobile supplier to experience the challenging manufacturing processes with advanced age. Scherf (2014) evaluated the effects of different Age Simulation Suit-modules on the installation performance of young (20-30-years-old) and older (50-60-years-old) assembly-workers of a big German automobile manufacturer, and demonstrated comparable performances of the young workers, wearing the least restrictive suit, and the older workers, wearing no suit.

Another field of interest is the health care or medical sector. Promoting empathy is a big concern in the education of medical professions, like doctors or nurses, and especially in geriatric medicine. Simulation trainings, like role-plays, simulation mannequins or the teaching method of "Instant Aging", represent an essential part of the curriculum for these professions (Braude et al., 2015; Fisher & Walker, 2013). Instant Aging creates a teaching and learning environment to experience the physical challenges of advanced age and/or certain typical diseases like vision and hearing loss, arthritis, hemiparesis, diabetes mellitus and Parkinson (Filz, 2009; Koytek, 2008; Kwetkat, Swoboda, & Singler, 2011). Qureshi, Jones, Adamson, and Ogundipe (2017) and Tremayne, Burdett, and Utecht (2011) used an Age Simulation Suit in everyday and working specific tasks to challenge the medical and nursing students' perspective of older patients and to promote awareness and understanding for the constraints of the older patients. Oral or written feedback of the young participants was very positive and highlighted the vivid and memorable effects of the simulation (Clark, Foos, & Faucher, 1995; Fisher & Walker, 2013; Oakley et al., 2014; Qureshi et al., 2017; Wood, 2003). A systematic review by Tullo, Spencer, and Allan (2010) states that these innovative teaching interventions have the potential to improve the knowledge and attitude of young medical students towards older patients, and that they are beneficial to promote empathy and a perspective takeover in these professions (but see Alfarah, Schünemann, & Akl, 2010, for a critical review of the effects of role playing interventions in geriatric medical education).

Previous studies focused on age simulation as a teaching and learning tool and therefore collected qualitative data about the effect of the intervention, usually by asking for self-reports. To our knowledge, very few studies investigated the quantitative performance changes in certain tasks due to wearing an Age Simulation Suit (Lauenroth, Schulze, Ioannidis, Simm, & Schwesig, 2017; Lavallière et al., 2016; Scherf, 2014; Zijlstra, Hagedoorn, Krijnen, van der Schans, & Mobach, 2016). Zijlstra et al. (2016) investigated the effect of an age simulation on wayfinding. They found that wearing a suit results in lower speed and higher heart and respiratory rates in young adults compared to not wearing the suit. Lavallière et al. (2016) studied how an Age Simulation Suit influences several clinical tests (postural balance, neck/shoulder range of motion, low back/hamstring flexibility and 10m-walk) and an experiential learning task. Young adults wearing the simulation suit showed a significant decline in almost all clinical tests, including a reduced velocity and an increased number of steps and time to walk the 10m distance. The effects of an Age Simulation Suit on several gait parameters as velocity, step length, step time and base width were analyzed by Lauenroth et al. (2017). Their results for step length and velocity indicated a reduction similar to an "age increase of 20 to 25 years" (p. 5) of young adults wearing the suit compared to the results of older adults.

To summarize, previous studies showed performance or physiological declines when wearing an Age Simulation Suit, but only Scherf (2014) and Lauenroth et al. (2017) compared the performances of younger adults wearing an Age Simulation Suit with the performances of older adults within the same tasks. These results consistently show performance decrements, but do not indicate a certain target age that can be simulated by wearing an Age Simulation Suit. We argue that effects of Age Simulation Suits should be investigated in different domains of functioning, like gross motor tasks, fine motor tasks, and even cognitive performances and self-perception. The Functional Fitness test (Rikli & Jones, 1999a, 1999b) and the Purdue Pegboard test (Lafayette Instrument, 2015) are well established tests for gross- and fine motor functioning. They assess physical resources that are necessary to perform everyday tasks, such as to go shopping, or to thread a thread into a needle. Both tests provide norms for seniors, allowing us to empirically measure whether the performances of young adults wearing the suit can be compared to the performances of older adults of specific age ranges.

There is empirical evidence for gender differences for many subtasks of these tests. For the Purdue Pegboard test, women perform better than men for all subtasks (Agnew, Bolla-Wilson, Kawas, & Bleecker, 1988; Sattler & Engelhardt, 1982; Yeudall, Fromm, Reddon, & Stefanyk, 1986). On the Functional Fitness test (Rikli & Jones, 1999b), men score better on strength, aerobic endurance, and agility/balance compared to women, wheras women show better flexibility. We use the norm data for both genders, and recruited equal numbers of males and females for our study.

In addition to changes in standardized performance measures, wearing an Age Simulation Suit can also affect mood and perceived physical state. We hypothesize that wearing the suit and perfoming a variety of tasks will be rather challenging and exhausting, so mood and perceived physical state will probably deteriorate in this condition.

The purpose of the present study was twofold: a) In a within-subjects design, we wanted to investigate if an Age Simulation Suit affects various performance domains, so we chose motor and cognitive tasks, as well as self-perceptions of physical state and mood. b) We wanted to evaluate the extent to which performances of young participants are reduced by wearing the suit, and whether young adults actually reach the performance level of older adults when wearing the suit. For the motor domain, we chose the Functional Fitness test (gross motor skills) and the Purdue Pegboard test (fine motor skills) to compare the data of the young participants wearing the suit to published age norms on the respective tests. We predict that wearing an Age Simulation Suit results in decrements in motor and cognitive performances, and influences perceived physical state and mood.

Methods

Participants

Since the manufacturer of the GERT suit (Moll, 2019a) claims that the suit causes performance decrements corresponding to 30-40 years of chronological age, we expected large effect sizes. We also argue that large effects are necessary if such suits are to be useful tools in future research. We conducted an a priori power analysis using G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007) to test the performance difference between the suit and no suit-condition, with a large effect size ($f = .40$), an alpha of .05, and a correlation among repeated measures of $r = .50$. Result showed that a total sample of 19 participants was required to achieve a power of .90.

We recruited twenty young adults ($M_{age} = 22.3$ years, 10 women). All participants had no history of neurological disease or musculoskeletal dysfunctions and had normal or corrected-to-normal vision. The participants had no prior experience with the tasks and were not aware of the specific purpose of the study. All participants except one were right-hand dominant as determined by the Edinburgh Handedness Inventory (Oldfield, 1971) prior to the experiment. Subjects were undergraduate sport students and were given course credit for their participation. Informed consent was obtained prior to participation in the experiment. The study was approved by the Ethics committee of Saarland University.

Age Simulation Suit

As an Age Simulation Suit, the model GERT (see Figure 1) from Moll (2019b) was used. This suit is designed to simulate consequences of physical aging on multiple dimensions. Reduced sensory acuity and tactile perception, by wearing disposable plastic gloves, and reductions in vision and hearing are intended. Colored glasses narrow the field of vision and create a blurry image. The earmuffs affect hearing, especially for higher frequencies. Bandages on elbows, knees and wrists should reduce flexibility and range of motion of these joints. The plastic gloves and the fingerless leather gloves restrict the grip ability and agility of the fingers. Note that the leather gloves only partially cover the fingers so as not to interfere with the reduced tactile perception simulated by the plastic gloves worn under the leather. A neck ruff leads to decreased agility of the head. Additional weights, 1.5 kg on each wrist, 2.3 kg on each ankle and a 10 kg upper-body-vest, affect strength and coordination abilities. Decreased balancing ability and insecure standing and gait are intended by wearing overshoes, with a 1.5 cm thick soft foam sole (see Figure 1).

[Insert Figure 1 here]

Experimental group, task and procedure

All participants performed two testing sessions, approximately 24 hours apart, one with the Age Simulation Suit and one without the suit. The order of testing sessions was counterbalanced, and males and females were distributed equally across the two counterbalancing conditions. In both conditions, the current physical feelings of the participants were assessed with the Perceived Physical State ("PEPS", Kleinert, 2006), a questionnaire of 20 adjectives representing four dimensions: physical energy (e.g., flabby, washed out), physical fitness (e.g., well trained, strong), physical flexibility (e.g., flexible, elastic), and physical health (e.g., sick, injured) (Kleinert, 2007). The perceived physical state was assessed with a six-point rating scale ranging from "not at all" (0) to "totally" (5). The current mood state of the participants was measured with the short Mood Scale ("MS", Wilhelm & Schoebi, 2007), a questionnaire of six bipolar items that measures three dimensions of mood: energetic arousal (e.g., tired – awake), valence (e.g., content – discontent) and calmness (e.g., relaxed – tense). Afterwards participants performed the Functional Fitness test ("FFT", Rikli & Jones, 1999a, 1999b), a screening battery to assess four motor dimensions: strength, flexibility, aerobic endurance and balance/agility.

Strength

The numbers of full chair stands with arms folded across the chest (leg strength) and the numbers of biceps curls holding a 2.9 kilogram (women) or 4.4 kilogram (men) hand weight (arm strength) were assessed, with 30 seconds for each test.

Flexibility

For hip flexibility, participants sat at the edge of a chair with one extended leg and tried to reach as far forward as possible toward (or beyond) the toes (chair sit-and-reach task). Distance was measured from the extended fingers to the tip of the toe. Note, positive numbers indicate reaching beyond the toes and negative numbers mean reaching short of the toes. Shoulder flexibility was assessed by trying to reach the middle finger of the other hand behind the back with one hand reaching over the shoulder and one up the middle of the back (back-scratch task). Again, the distance (or amount of overlap) between both middle fingers was measured and positive numbers indicate that the fingers overlap and negative numbers that the fingers cannot reach. Both flexibility tasks were performed with the more mobile limb and with two attempts for each task. The better attempt was scored.

Aerobic endurance

Participants had to step for 2 minutes, by raising each knee to a minimum height as often as possible. The minimum height represents half of the length of the thigh, measured as the distance between the kneecap and the anterior hip bone, and was calculated individually for each participant. The individual height was marked on the wall as a reference point.

Balance and agility

Balance and agility were tested with the 8-feet timed-up-and-go task (“TUG”). Participants rise up from a chair, walk a distance of 8-feet and circle a pylon, and sit down again in the shortest time possible. The better out of two attempts was scored.

The FFT was assessed with the following task order in each session: leg strength, arm strength, aerobic endurance, hip flexibility, shoulder flexibility and balance/agility. We compared the FFT-results of the young adults wearing the suit with normative data from Rikli and Jones (1999b), who tested over 7.000 community-residing American older adults aged 60-94 years.

As a cognitive measure the Digit-Symbol Substitution test ("DS", Wechsler, 1981) was chosen to assess perceptual speed. Participants were presented with combinations of digits and abstract symbols. Test sheets contain rows of digits in random order, with blank spaces underneath. Participants are asked to fill in as many blank spaces as possible with the correct symbol in 90 seconds. After the DS, all participants answered the PEPS and MS for a second time, so that both questionnaires were assessed at the beginning and middle of each testing session.

Fine motor skills were assessed with a shirt-buttoning task and the Purdue Pegboard test (“PPT”, Lafayette Instrument, 2015). In the buttoning-task, participants must button up seven buttons of a shirt and open them again as often as possible in 60 seconds.

The PPT measures unimanual and bimanual finger and hand dexterity with four subtests. The pegboard consists of two parallel rows of 25 holes each. Participants have to place as many metal pins as possible in a row, either with their dominant hand, their non-dominant hand, or with both hands, within a 30-second time period (first three subtests). In the fourth subtest participants use both hands alternately to construct assemblies, which consist of four elements (a pin, a washer, a collar, and a second washer). Participants must complete as many assemblies as possible within one minute. We compared the PPT-performances of the young participants wearing the Age Simulation Suit with normative data from Agnew et al. (1988) based on 212 healthy 40-85-year-old adults.

Statistical analysis

Statistical analyses were computed with SPSS for Windows version 24.0 (IBM Corp., Armonk, NY, USA). Analyses of task performances with the Age Simulation Suit and without the suit were computed using mixed-design analyses of variance (ANOVA) with suit (2: suit, no suit) as within-subjects factor and gender (2: female, male) as between-subjects factor. Analyses of the questionnaires were computed using mixed-design ANOVAs with suit (2: suit, no suit) and order (2: beginning vs. middle of the respective session) as within-subjects factors and gender (2: female, male) as between-subjects factor. The effect size partial eta square (η_p^2) was determined for all significant effects (Cohen, 1988). The alpha level of .05 was used to interpret statistical significance. Significant main effects and interactions effects were followed by simple main effect analyses.

Results

Table 1 presents mean performances without the suit, when wearing the suit, the performance decrement expressed as a percentage score, and the age norms of the respective subtest for males and females in the FFT test. For the percentage scores, the difference from “Suit” to “No Suit”, divided by “No Suit”, was calculated. Multiplication by 100 yielded the respective %-values. Table 2 presents the same data for the PPT. Figure 2 shows the performance decrements for all subtests of the gross and fine motor tasks, the cognitive performance, and the ratings of perceived physical and emotional state. Wearing the Age Simulation Suit (ASS) leads to significant performance reductions in all measures.

[Insert Figure 2 here]

Functional Fitness test

Strength

Leg

The analysis of full stands detected a significant main effect of suit, $F(1, 18) = 35.10$, $p < .001$, $\eta_p^2 = .66$. The main effect of gender and the interaction of suit × gender failed to reach significance. Despite the pronounced decrements while wearing the suit, in comparison to normative data from Rikli and Jones (1999b), the performance of female and male participants wearing the ASS was still much better than the performance of 60-64-year-old community-residing adults (see Table 1).

Arm

The results of the numbers of biceps curls showed a significant main effect of suit, $F(1, 18) = 41.65$, $p < .001$, $\eta_p^2 = .70$, and gender, $F(1, 18) = 6.05$, $p < .05$, $\eta_p^2 = .25$. The interaction of suit × gender did not reach significance. Men achieved more biceps curls than women. Results of young men wearing the suit are slightly better than for 60-64-year-old men. They can be estimated to represent performances of men in their mid-fifties. The results of the women are comparable to 60-64-year-old women (see Table 1).

Aerobic endurance

Stepping

The analysis detected a significant main effect of suit, $F(1, 18) = 137.83$, $p < .001$, $\eta_p^2 = .88$, and gender, $F(1, 18) = 4.63$, $p < .05$, $\eta_p^2 = .21$, but no significant interaction of suit × gender. The main effect of gender revealed a worse performance of women compared to men. Young women and men wearing the ASS showed better results than 60-64-year-olds, with women probably being roughly comparable to women in their late fifties and men being comparable to men in their early fifties (see Table 1).

Flexibility

Hip

The analysis detected a significant main effect of suit, $F(1, 18) = 19.29$, $p < .001$, $\eta_p^2 = .52$, but no significant main effect of gender, and no interaction of suit × gender. The performance of female and male participants with the ASS was much better than comparable results of 60-64-year-olds (see Table 1).

Shoulder

The analysis detected a significant effect of suit, $F(1, 18) = 207.92$, $p < .001$, $\eta_p^2 = .92$. The main effect of gender and the interaction of suit × gender failed to reach significance. As shown in Table 1, while wearing the ASS, females and males perform at the level of 65-69-year-olds.

Balance/Agility

TUG

For the TUG, there was a significant effect of suit, $F(1, 18) = 208.30$, $p < .001$, $\eta_p^2 = .92$, but no significant effect for gender, and no interaction of suit × gender. The performances with the ASS of the young female and male participants are better than the results of 60-64-year-old adults, and can be estimated to be equivalent to middle-aged performances (see Table 1).

[Insert Table 1 here]

Fine motor tasks

Purdue Pegboard test

Dominant hand

The analysis showed a significant main effect of suit, $F(1, 18) = 127.08$, $p < .001$, $\eta_p^2 = .88$. The effect of gender and the interaction of suit × gender did not reach significance. The comparison with normative data from Agnew and colleagues (1988) showed that wearing the ASS resulted in performances that are comparable to men in their late seventies or early eighties and to 80-89-year-old women (see Table 2).

Non-dominant hand

The results indicated a significant main effect of suit, $F(1, 18) = 105.50$, $p < .001$, $\eta_p^2 = .85$, but no significant effect for gender or for the interaction of suit × gender. The results of the young men and women wearing the ASS are comparable to the results of older adults who are about eighty years old (see Table 2).

Both hands

The analysis detected a significant main effect of suit, $F(1, 18) = 187.74$, $p < .001$, $\eta_p^2 = .91$, gender, $F(1, 18) = 5.85$, $p < .05$, $\eta_p^2 = .25$, and a significant interaction of suit × gender, $F(1, 18) = 7.20$, $p < .05$, $\eta_p^2 = .29$. The main effect of gender showed a superior performance of women in comparison to men. Simple main effect analysis for suit across gender showed a significant effect for the no suit-condition, with women ($M = 13.90$, $SD = 1.40$) performing superior in contrast to men ($M = 11.80$, $SD = 1.20$), $t(18) = 3.63$, $p < .01$, and no significant gender difference in the suit-condition. The performance of the female participants is comparable to results of women who are about eighty years old and the male participants are comparable to men in their early eighties (see Table 2).

Assembly

The analysis showed a significant main effect of suit, $F(1, 18) = 229.87$, $p <$

.001, $\eta_p^2 = .93$. The main effect of gender and the interaction of suit × gender failed to reach significance. The results of both young men and women with the ASS are comparable to older adults being about eighty years old (see Table 2).

[Insert Table 2 here]

Shirt-buttoning

The analyses were conducted with nineteen participants because one male participant did not fit into the shirt. The results indicated a significant main effect of suit, $F(1, 18) = 162.55$, $p < .001$, $\eta_p^2 = .90$, but no significant effects of gender, and no interaction of suit × gender. The main effect of suit revealed a performance decrease, with participants buttoning 25 buttons (*SD* = 4.85) in the no suit-condition, and only 9 buttons (*SD* = 4.06) when wearing the suit.

Cognitive measure and questionnaires

Digit Symbol

For Digit Symbol, there was a significant main effect of suit, $F(1, 18) = 13.84$, $p < .01$, $\eta_p^2 = .44$, but no significant effects were revealed for gender or for the interaction of suit × gender.

Physical and Mood State

Because of missing data from one participant, nineteen participants were analyzed. Analyses of the questionnaires were computed using mixed-design ANOVAs with suit (2) and order (2) as within-subjects factors and gender (2) as between-subjects factor. For the current Perceived Physical State (PEPS) and the current Mood State (MS) questionnaires, a significant main effect of suit appeared for all dimensions. Except for the dimension "energetic arousal" of the MS, a significant main effect of order was revealed for all dimensions of both questionnaires. The main effect of gender failed to reach significance for both questionnaires. The interaction of suit × order was significant for all dimensions of the two questionnaires (see Table 3).

The main effect of order indicated a decrease in the perceived physical and emotional state after performing the FFT and the DS, in comparison to the beginning of the session. As can be seen in Table 3, the interaction of suit and order was due to decreases in perceived physical state and mood in the session with the suit, while there were no differences between the beginning and middle of the session in the no suit-condition. The only exception was the subscale "activity" of the PEPS, $t(18) = 2.60$, $p < .05$, which showed a reduction from the beginning ($M = 3.95$, $SD = 0.90$) to the middle of the session ($M = 3.54$, $SD = 1.08$) in the no suit-session as well.

[Insert Table 3 here]

Discussion

In the present experiment we investigated the effects of an Age Simulation Suit on multiple performance domains, namely motor and cognitive tasks, as well as self-perception of physical and emotional state. As predicted, wearing an Age Simulation Suit resulted in pronounced performance decrements in gross and fine motor tasks and in a cognitive task. When performance reductions are expressed in percentages, participants lose on average between 12 and 26 percent in the gross motor tasks and between 20 and 30 percent in the fine motor tasks when wearing the suit. The only exception is the shoulder flexibility test, for which performances deteriorate by up to

350 %. Wearing the suit also influenced the perception of physical state and mood of the young adults.

Compared to age norms of the Functional Fitness Test (Rikli & Jones, 1999b), wearing the suit reduced young adults' performances for "leg strength", "hip flexibility" and the "balance/agility", but performances were still higher than in the age norms for 60-64-year-olds. Performances for the subtests "arm strength" and "2 min-stepping" were still better than performances of 60-64-year-old community-residing women and men, but the differences to the 60-64-year-old sample were attenuated. Performances for the "shoulder flexibility" test were more impaired by wearing the suit, and were comparable to 65-69-year-old women and men.

For the fine motor control required in the Purdue Pegboard test, the performances of the young adults wearing the Age Simulation Suit were comparable to the performances of about eighty-year-old adults in the subtests "non-dominant hand" and "assembly". For the "dominant hand" and "both hands", their performances were comparable to performances of older adults in their late seventies or early eighties (see Agnew et al., 1988).

The heterogeneous pattern of performance decrements with regard to the published age norms can be interpreted in various ways. The superior performances in some subtests of the FFT could be due to the selection of the participants. We only tested sport students who participate in at least one sport or fitness course a week, which might lead to a better "overall" fitness, in contrast to a less fit and also more heterogeneous peer group. In addition, some subtests might be more demanding than others, involving whole-body movements. For instance, the number of full stands within 30 sec measures isolated leg strength, while 2 min-stepping involves the whole body, by coordinating arm and leg movements, and is made more difficult by carrying all the weights.

We only assessed one specific Age Simulation Suit (GERT), and do not know whether our findings would generalize to other models. We assume that not all tasks are restricted equally by the components of the suit. For example, the performance decrements in the "shoulder flexibility" task are possibly also influenced by the size of the weights around participants' wrists. These biomechanical constraints could make it harder to reach the other hand. The fine motor tasks of the Purdue Pegboard test are made more difficult in several ways. The tactile perception of the fingertips, the strength and mobility of the finger and hand, as well as the ability to coordinate the grasping movement are reduced simultaneously, by wearing two types of gloves. In addition, the reduced vision caused by the colored glasses could also have a major influence on these subtests. Future research using a systematic manipulation of the individual components is necessary to disentangle their influence on specific types of performances.

We also found performance declines in cognition, as measured by the performance in the Digit Symbol Substitution test. This paper-and-pencil test requires to perceive a target symbol and to accurately and quickly copy it into the respective field. The Digit Symbol Substitution test measures perception and processing speed, which are seen as predominantly cognitive functions (see S.-C. Li et al., 2004; Wechsler, 1981). However, performance on the test is also affected by sensory and motor processes. We assume that performance declines in our paradigm were mainly caused by visuomotor aspects, as changes in visual acuity and in the fine-motor control of fingers and hands. However, it is possible that other cognitive tasks requiring less precise visual input and less or no fine motor control also suffer from wearing an Age Simulation Suit. In future research, the Age Simulation Suit can illustrate the importance of sensorimotor processes even in predominantly cognitive tasks. The suit has no direct influence on the neuronal integrity of the brain, but only influences sensory and motor processes. Concerning age-related cognitive and motor decline, future research with this paradigm can hopefully contribute to the debates on common or specific causes for cognitive and motor declines in older ages (Cai, Chan, Yan, & Peng, 2014; K. Z. H. Li & Lindenberger, 2002; Lindenberger, Scherer, & Baltes, 2001; Schaefer, Huxhold, & Lindenberger, 2006), by offering an attractive possibility to experimentally influence some of the underlying factors. This approach could also help to identify tasks that represent a "purer" measure of cognition than some of the classic paper-and-pencil measures that are often used in neuropsychological assessments.

In a similar vein, age simulations could be used in research on cognitive-motor dual-tasking across the adult lifespan. Older adults have often been shown to have higher decrements when performing a cognitive and a motor task simultaneously, since they have to invest attentional resources into seemingly automatized motor tasks. They also tend to prioritize the motor tasks (Al-Yahya et al., 2011; K. Z. H. Li, Lindenberger, Freund, & Baltes, 2001; Schaefer, 2014; Woollacott & Shumway-Cook, 2002). Do young adults behave similarly when wearing an Age Simulation Suit? Does wearing such a suit also influence their strategic decisions, for example when choosing a suitable level of task-difficulties (Riediger, Li, & Lindenberger, 2006)?

Concerning motor learning, can the Age Simulation Suit slow down the process of motor learning and if so, how long would it take for the young adults to get used to these restrictions? Do they develop alternative strategies to deal with the limitations in an early learning stage (see Brand & de Oliveira, 2017; van Andel, Cole, & Pepping, 2017, for literature on recalibration), or are there motor learning tasks for which the restrictions cannot be compensated for?

Changes in the current physical and mood state of the young adults demonstrate that the Age Simulation Suit has a strong impact on the participants' self-perception.

Feeling like an older adult, both emotionally and physically, has the potential to create awareness of the physical but also the psychological changes and challenges of aging. Such an experience can improve the attitude towards older adults, as several studies have previously shown (Qureshi et al., 2017; Tremayne et al., 2011; Tullo et al., 2010).

In conclusion the Age Simulation Suit GERT offers young healthy adults the opportunity to experience the process of normal physical and sensory aging, by reducing their performances in fine and gross motor and cognitive tasks, as well as influencing their physical and emotional self-perception. Our results show that wearing the GERT does not lead to a general aging of 30-40 years, as the manufacturer claims. Rather the performance decrements are dependent on the chosen abilities and tasks. For the Functional Fitness test the manufacturer's age specification roughly fits, whereas the performance decrements of the Purdue Pegboard test are much stronger. This performance variability could be seen as a good illustration of the real process of aging, which differs considerably among older people. Becoming older sometimes means facing serious health conditions and maybe losing one's independence, but it could also reflect a "successful aging" with fewer declines in physiological and social functioning and positive perceptions of life-satisfaction and well-being (see Cosco, Prina, Perales, Stephan, & Brayne, 2014, for a review). Having this in mind, the Age Simulation Suit offers a "general" experience of older age, representing the most common physical and sensory losses when becoming older. Therefore, when applying the suit in a particular setting, for example to simulate a specific age or level of difficulty, it may be necessary to make some adjustments to it (see also Scherf, 2014).

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Conflict of Interest

We have no conflict of interest to declare.

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Appendices

Table 1

Means and standard deviations for the six subtests of the Functional Fitness test for the female and male participants wearing the Suit, compared to normative data from Rikli and Jones (1999b, p. 169) for older adults. Note, normative data for hip and shoulder flexibility are modified, by using centimeter instead of inch.

Gender	Subtasks	No Suit	Suit	Change (%)	60-64 years	65-69 years	70-74 years	75-79 years	80-84 years	85-89 years
Female	Leg strength (n)	27.0 (4.0)	21.7 (3.3)	-19.4 (6.3)	14.5 (4.0)	13.5 (3.5)	12.9 (3.6)	12.5 (3.8)	11.3 (4.2)	10.3 (4.0)
	Arm strength (n)	19.7 (2.9)	16.6 (3.5)	-16.2 (10.6)	16.1 (4.6)	15.2 (4.3)	14.5 (4.4)	14.0 (4.4)	13.0 (4.1)	12.2 (3.8)
	Aerobic endurance (n)	122.4 (12.4)	93.5 (13.5)	-23.5 (8.8)	91 (24)	90 (26)	84 (25)	84 (24)	75 (23)	70 (22)
	Hip flexibility (cm)	25.7 (6.5)	21.2 (5.4)	-17.0 (12.1)	5.3 (10.2)	5.1 (9.1)	3.6 (9.4)	3.0 (9.7)	1.3 (9.4)	-0.3 (9.4)
	Shoulder flexibility (cm)	7.1 (5.5)	-3.3 (6.5)	-222.0 (153.5)	-1.8 (8.9)	-3.0 (9.4)	-4.3 (9.7)	-5.3 (10.4)	-6.6 (10.7)	-9.9 (11.4)
	Balance/ Agility (s)	3.6 (0.3)	4.4 (0.4)	-23.5 (5.2)	5.2 (1.2)	5.6 (1.2)	6.0 (1.6)	6.3 (1.6)	7.2 (2.2)	7.9 (2.5)
Male	Leg strength (n)	27.6 (4.9)	23.7 (4.1)	-13.1 (13.9)	16.4 (4.3)	15.2 (4.5)	14.5 (4.2)	14.0 (4.3)	12.4 (3.9)	11.1 (4.6)
	Arm strength (n)	23.5 (4.3)	20.6 (3.9)	-12.0 (7.4)	19.0 (4.7)	18.4 (5.3)	17.4 (5.0)	16.2 (4.6)	16.0 (4.3)	13.6 (4.3)
	Aerobic endurance (n)	130.5 (13.4)	107.5 (10.5)	-17.5 (4.4)	101 (21)	101 (23)	95 (23)	91 (27)	87 (24)	75 (24)
	Hip flexibility (cm)	17.8 (10.3)	14.8 (12.3)	-26.1 (37.3)	1.5 (12.2)	0.0 (11.7)	-1.0 (11.7)	-2.8 (11.9)	-5.1 (12.7)	-6.1 (10.7)
	Shoulder flexibility (cm)	2.8 (9.3)	-10.4 (12.0)	-350.2 (553.3)	-8.6 (12.2)	-10.4 (12.4)	-11.4 (12.4)	-14.2 (13.0)	-14.5 (13.7)	-15.7 (12.2)
	Balance/ Agility (s)	3.3 (0.3)	4.1 (0.5)	-22.3 (8.2)	4.7 (1.3)	5.1 (1.2)	5.3 (1.3)	5.9 (1.9)	6.4 (1.8)	7.2 (2.6)

Note. n = numbers, cm = centimeters, s = seconds.
Negative values for the %-change measure indicate performance deteriorations in the suit-condition.

Table 2

Means and standard deviations for the four subtests of the Purdue Pegboard test for the female and male participants wearing the Suit, compared to normative data from Agnew et al. (1988, p. 32) for older adults

Gender	Subtasks	No Suit	Suit	Change (%)	50-59 years	60-69 years	70-79 years	80-89 years
Female	Dominant hand (n)	17.3 (1.47)	12.8 (0.95)	-25.6 (6.74)	15.0 (1.56)	14.6 (2.03)	13.8 (1.27)	12.9 (1.80)
	Non-dominant hand (n)	15.8 (2.01)	12.0 (1.67)	-23.6 (9.04)	14.4 (1.69)	13.9 (1.78)	12.9 (1.52)	11.3 (2.05)
	Both hands (n of pairs)	13.9 (1.40)	9.8 (1.81)	-29.4 (10.17)	12.1 (1.30)	11.6 (1.87)	10.5 (1.19)	9.2 (1.92)
	Assembly (n)	39.4 (6.69)	25.8 (7.61)	-35.5 (12.14)	34.6 (8.21)	31.7 (6.83)	29.1 (4.85)	21.9 (4.54)
Male	Dominant hand (n)	15.3 (1.85)	12.2 (1.90)	-19.8 (10.60)	14.4 (2.15)	13.6 (1.74)	13.0 (1.90)	10.8 (1.33)
	Non-dominant hand (n)	14.6 (1.25)	11.5 (1.36)	-21.6 (7.91)	13.9 (2.19)	13.1 (1.56)	12.4 (1.48)	10.6 (1.84)
	Both hands (n of pairs)	11.8 (1.17)	9.1 (1.28)	-23.3 (6.26)	11.9 (2.22)	10.9 (1.46)	10.4 (1.27)	8.5 (1.21)
	Assembly (n)	34.7 (6.86)	24.3 (5.51)	-30.2 (7.25)	33.8 (9.66)	28.0 (5.06)	27.5 (5.06)	21.5 (4.81)

Note. n = numbers.
Negative values for the %-change measure indicate performance deteriorations in the suit-condition.

Table 3

Main effects and interaction effects for all dimensions of the Perceived Physical State and the Mood State-questionnaires

Questionnaires	Dimensions	Effects	Df-value	F-value	Partial eta square
Perceived Physical State	Energy	Suit		20.17***	.54
		Order	(1,17)	40.77***	.71
		Suit x Order		26.50***	.61
	Fitness	Suit		26.23***	.61
		Order	(1,17)	28.97***	.63
		Suit x Order		17.97**	.51
	Flexibility	Suit		4.55*	.21
		Order	(1,17)	9.23**	.35
		Suit x Order		19.87***	.54
	Health	Suit		6.28*	.27
		Order	(1,17)	9.73**	.36
		Suit x Order		12.37**	.42
Mood State	Energetic arousal	Suit		16.43**	.49
		Order	(1,17)	1.24	.07
		Suit x Order		6.83*	.29
	Valence	Suit		29.32***	.63
		Order	(1,17)	15.87**	.48
		Suit x Order		30.29***	.64
	Calmness	Suit		6.89*	.29
		Order	(1,17)	9.87**	.37
		Suit x Order		23.50***	.58

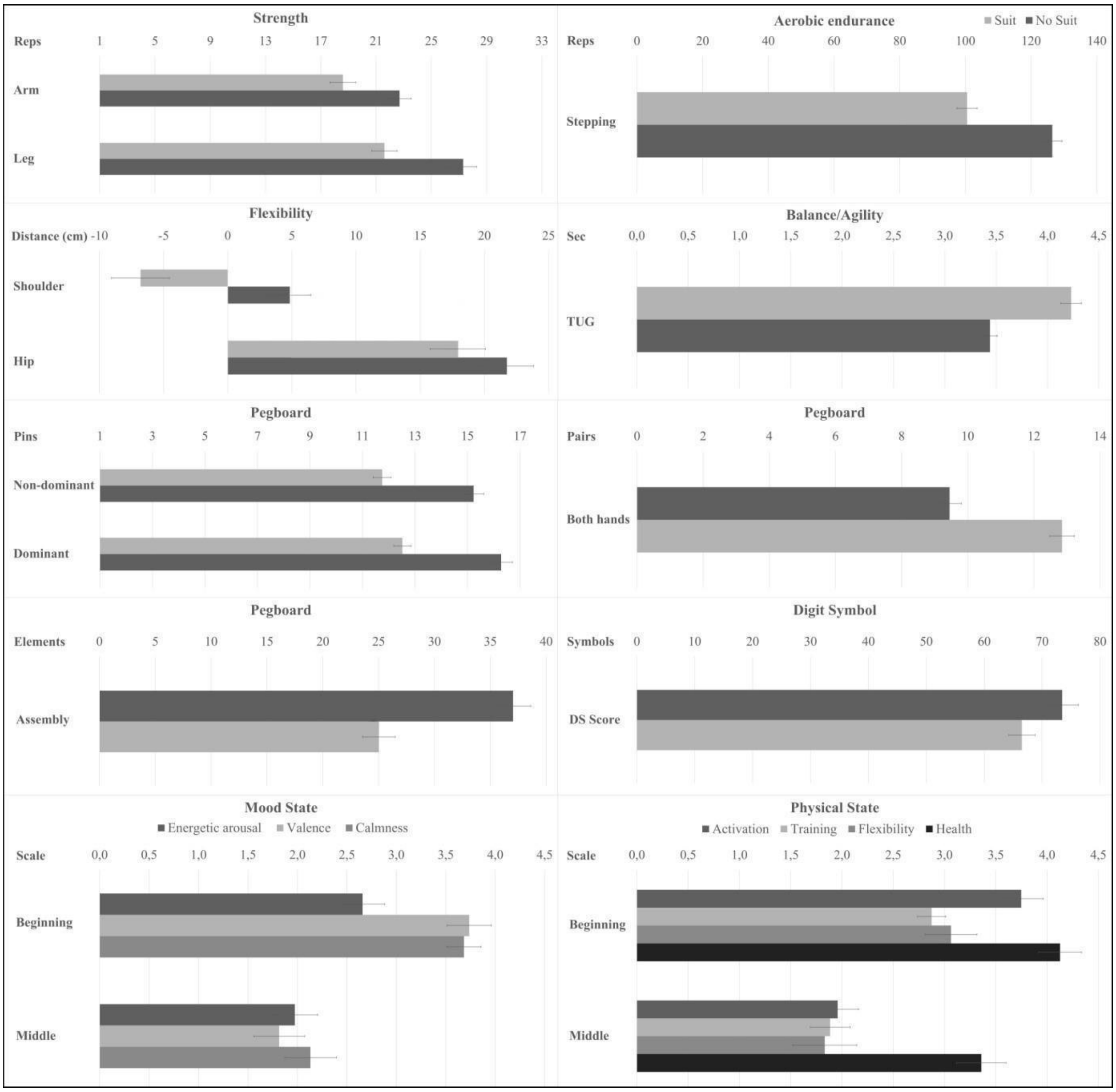
Note. * = $p < .05$, ** $p < .01$, *** = $p < .001$.

Figures

Figure 1. The Age Simulation Suit GERT.

Figure 2. Comparisons of the Suit- (light gray) and No Suit-condition (dark gray) for all subtests of the Functional Fitness test (Strength, Aerobic endurance, Flexibility and Balance/Agility), the Purdue Pegboard test (Dominant hand, Non-dominant hand, Both hands and Assembly) and the Digit Symbol Substitution test (Score). Changes from the beginning to the middle of the sessions in Mood State (dimensions: Energetic arousal, Valence and Calmness) and Physical State (dimensions: Activation, Training, Flexibility and Health) are displayed only for the Suit-condition. All results are represented by the means and their respective standard errors.

Figure 1.



Strength
Reps
1
5
9
13
17
21
25
29
33
Arm
Leg
Aerobic endurance
Suit
No Suit
Reps
0
20
40
60
80
100
120
140
Stepping
Flexibility
Distance (cm)
-10
-5
0
5
10
15
20
25
Shoulder
Hip
Balance/Agility
Sec
0,0
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1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
TUG
Pegboard
Pins
1
3
5
7
9
11
13
15
17
Non-dominant
Dominant
Pegboard
Pairs
0
2
4
6
8
10
12
14
Both hands
Pegboard
Elements
0
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20
25
30
35
40
Assembly
Digit Symbol
Symbols
0
10
20
30
40
50
60
70
80
DS Score
Mood State
Energetic arousal
Valence
Calmness
Scale
0,0
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2,5
3,0
3,5
4,0
4,5
Beginning
Middle
Physical State
Activation
Training
Flexibility
Health
Scale
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
Beginning
Middle

Figure 2.

Anhang 4: Beitrag 4

Vieweg, J., Leinen, P., Verwey, W. B., Shea, C. H., & Panzer, S. (2020). The cognitive status of older adults: Do reduced time constraints enhance sequence learning? *Journal of Motor Behavior, 52*(5), 558-569. https://doi.org/10.1080/00222895.2019.1654970

The cognitive status of older adults: Do reduced time constraints enhance sequence learning?

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Abstract

Research has indicated that older adults perform movement sequences more slowly than young adults. The purpose of the present experiment was to compare movement sequence learning in young and older adults when the time to perform the sequence was extended, and how the elderly's cognitive status (Montreal Cognitive Assessment [MoCA]) interacted with sequence learning. The task was to minimize the difference between a target sequence pattern and the sequence produced by elbow extension-flexion movements. On Day 1, participants (28 young adults; 28 older adults) practiced the sequence under two time windows: 1300 ms or 2000 ms. On Day 2, retention performance and the cognitive status were assessed. The results demonstrated that young adults performed superior compared to older adults. Additional time to perform the sequence did not improve retention performance for the older adults. The correlation between the error score and the MoCA score of $r = -.38$ ($p < .05$) in older adults indicated that a better cognitive status was associated with performance advantages in sequence learning.

Keywords: sequence learning; aging; cognitive status

The cognitive status of older adults: Do reduced time constraints enhance sequence learning?

Age-related decline of motor learning has been demonstrated in a wide range of tasks (e.g. Bo, Borza, & Seidler, 2009; Panzer, Gruetzmacher, Ellenbürger, & Shea, 2014; Verwey, 2010; Voelcker-Rehage, 2008 for a review; Welsh, Higgins, & Elliot, 2007). For example, Voelcker-Rehage and Alberts (2005) used a force modulation task, in which young and older participants were instructed to produce isometric forces between the thumb and the index finger during 30 s to move a cursor on a target pattern presented on a screen. In the study of Verwey (2010) young adults and older adults practiced sequences of 3 and of 6 key presses. In this type of task, the participants were instructed to press spatial corresponding keys in a discrete manner to visual presented stimuli on the screen as quickly as possible. Shea, Park, and Braden (2006) used a continuous, dynamic movement sequence task in which older and young participants moved a lever to visual presented targets as quickly and smoothly as possible by an extension-flexion forearm movement. Regardless of the tasks in all cited experiments young adults outperformed older adults. The age-related regressive changes in motor performance and learning are reflected in movement slowing down, less reproducible motor responses, and less harmonic movements (Boyle, Kennedy, & Shea, 2015; Panzer, Gruetzmacher, Fries, Krueger, & Shea, 2011; Seidler, 2006; Shea, Kennedy, & Panzer, 2019; Verwey, 2010; Welford, 1984).

Although a number of physiological factors on the neuromuscular level contribute to the regression (e.g., sarcopenia, synaptic transmission delays, reduced excitability, reduced nerve conduction velocity, reduced muscle contractile speed, difficulty to adequately control agonist and antagonist), the mechanisms underlying behavioral slowing and the production of more variable motor responses are not well understood (Bo et al., 2009; Smits-Engelsman, van Galen, & Duysens, 2004). Numerous theorists in cognitive psychology (e.g., Verhaeghen & Salthouse, 1997 for a review) and motor learning (e.g., Cai, Chan, Yan, & Peng, 2014; Voelcker-Rehage, 2008 for reviews) have focused their attention on a possible decline resulting in behavioral slowing. Especially age-related decline in cognitive performance has received a good bit of experimental attention. The pattern of results, perhaps oversimplified, showed that age-related decline is determined more by central cognitive mechanisms than by peripheral processes (e.g., Chaput & Proteau, 1996; Welford, 1982). However, the amount of age-related changes is a controversial question. For example, in a longitudinal study Hayden et al. (2011) evaluated age-related changes during 15 years in a sample of priests, nuns and brothers. Their findings indicated that the cognitive decline in this subsample was relatively slow. Demonstrations and explanations of age-related differences in cognitive processes are provided by previous research in neuroscience and cognitive psychology. In the cognitive science literature working memory, discrimination, and recognition are associated with cognitive processing and they are often the object of contemplation in the research of age-related differences (Cai et al., 2014).

For example, the impact of aging on working memory and cognition was investigated in a study with positron emission tomography by Reuter-Lorenz et al. (2000). They showed age-related decline in the performance of the verbal and the spatial working memory, and this decline was reflected in a bilateral activation of both hemispheres (see also Bo et al., 2009). In a behavioral experiment to study cognitive functions, Starns and Ratcliff (2010) demonstrated with a letter discrimination task and a recognition memory task that older adults take more time to gather the required information before performing the tasks than young adults. As a result response time increases (see also Heitz, 2014 for a review of speed and accuracy idea). This led authors to conclude that older adults focus more on accuracy to avoid errors than on speed (Salthouse, 1979; Starns & Ratcliff, 2010).

These findings from cognitive psychology are accompanied by some results reported in the motor learning literature. Verneau, van der Kamp, Savelsbergh, and de Looze (2014) used a variant of a serial reaction time task to test the time effects on implicit and explicit movement sequence learning in older adults. Their results indicated that older adults benefit from a reduced time constraint to perform an explicit sequence learning task (see Cleeremans & Sarrazin, 2007 for a more general view). The aging research also shows a steady decline in motor sequence learning over age typically explained as result of reduced cognitive processing (Howard & Howard, 2001). The maintenance of working memory capacity (Maxwell, Masters, & Eves, 2003) or the ability to process different information about tasks simultaneously such as processing actual feedback information during sequence execution and information to use in advance to prepare/execute the next element or grouped elements of the sequence (de Kleine & van der Lubbe, 2011; Salthouse, 1996; Verwey, 2010) seem crucial for movement sequence learning.

Panzer and colleagues (2014) provided empirical evidence that older adults tend to rely on closed loop control in movement sequence learning. They conducted an experiment to test the development of a movement sequence representation. In an inter-manual practice design young and older participants performed a simple preplanned spatial-temporal pattern with a sequence of three reversals, by extending and flexing the elbow in a given timeframe of 1300 ms across two days with the right and left limb. The results of the study indicated that older adults had problems in developing a specific movement sequence representation and they were actually less accurate in spatial performance than young adults. Note the spatial-temporal pattern disappeared after movement initiation. This led the authors to conclude that without the external visual feedback during sequence execution and the short duration of the sequence, older participants do not have the opportunity for a closed loop control to specify the movement plan (see also Adams, 1971; McNay & Willingham, 1998, Seidler & Stelmach, 1995). Extended time to execute a movement increases the likelihood that participants have enough time to utilize feedback based control loops to compare the visual or proprioceptive information with a movement plan or a 'blueprint of the movement' initiated prior to the movement to perform the task as accurate as possible (Potter & Grealy, 2008; Sarlenga, 2006; Verneau, van der Kamp, de Looze, & Savlesberg, 2016). In other words, shorter duration movements rely predominantly on pre-planning, while longer duration movements have an initial pre-planned component after which movement control is gradually taken over by closed loop control (Glover, 2004). Pre-planning processes require the selection and programming of the appropriate information, including the timing and the velocity of the movement to reach the target. In short duration movements where the time to perform a task is constrained planning and executing of the movement sequence induces simultaneous processing operations. According to the limited time idea, it can be assumed that one of the relevant operations is executed to slow and reduces the amount of simultaneously present information that is needed to successfully process in the available time (Salthouse, 1996). In longer duration movements closed loop control can occur, because feedback loops to govern the movement have time to close, allows an updating of the commands to correct the movement (Bastian, 2006), and monitors the movement progress 'in flight' (Glover, 2004). This conclusion is also supported by the information-processing approach. According to the information-processing approach the human sensorimotor system has an inherent ability to correct errors during response execution using external visual information about the limb position relative to the movement goal and internal proprioceptive information arising from the muscles and other sensory systems within the performer. Recent research consistently demonstrated a general decline in information processing speed with increased aging (e.g., Keele & Posner, 1968; Shea et al., 2019).

Theories in cognitive psychology consider motor processes as a 'late' out-put related aspect in the information-processing approach which can be investigated independently from the 'central' cognitive processes. However, it has to be considered that motor processes represent a particularly important part of the task. Although there are several approaches in the cognitive psychology research and the motor control and learning research to explain age-related decline, 'it is no longer acceptable to think of a unitary cause' (Seidler & Stelmach, 1995, p. 387) of the regressive changes with advanced aging.

The purpose of the present experiment was twofold: (a) to investigate sequence learning when young and older adults were required to respond to a target sequence pattern as accurately as possible when the time for sequence production was systematically extended, and (b) to investigate how the cognitive status interacts with sequence learning. Note the first purpose of the experiment was formulated, in part, based on previous results of the experiment conducted by Panzer and colleagues (2014) which indicated that extended time to perform the sequence may increase the likelihood for closed loop control. Given the assumption that ‘older adults prize accuracy more than speed’ (Yu, 2012), can they increase sequence production accuracy when the time to produce the sequence is systematically extended (Verneau et al., 2014)? Note that additional time to perform a task increases the likelihood of closed loop control, retaining visual, spatial and proprioceptive information in working memory (Reuter-Lorenz et al., 2000; see also Adams, 1971). If older adults emphasize accuracy they should improve movement accuracy when more time is available.

Seidler and Stelmach (1995) argue for a more integrative research of cognitive science and motor control and learning. Therefore, another interesting question is to determine the extent to which the cognitive status of the older performers related to movement sequence performance and learning. Due to the fact that cognitive processes, for example working memory processes, deteriorate with age (Verneau et al., 2014) we predict that the correlation between the cognitive status and sequence learning is higher in older adults compared to young adults.

Method

Participants

Young adults (N=28; 23 - 29 years of age) and older adults (N=28; 65 - 78 years of age) participated in the experiment. All participants had no history of neurologic disease, stroke, color blindness nor musculoskeletal dysfunctions and had normal or corrected-to-normal vision. The participants had no prior experience with the experimental task and were not aware of the specific purpose of the study. All participants were right-hand dominant as determined by the Edinburgh Handedness Inventory (Oldfield, 1971) prior to the experiment. Informed consent was obtained prior to participation in the experiment. The young adults were undergraduate students and were given course credit for participation. All older adults were physically active and involved in the fitness program offered by the University for senior studies and they received compensation for travel expenses (7.50 € each) for their participation. The experiment was conducted in accordance with the revised version of the Declaration of Helsinki (2008). The characteristics of the young and older participants across the different groups are reported in Table 1.

Insert Table 1 here

Apparatus

The apparatus consisted of a horizontal lever, supported at the proximal end by a vertical axle that turned almost frictionless in a ball-bearing support. The lever was fixed on the right side of a table allowing the lever to move in the horizontal plane over the table. At the other end of the lever there was a vertical handle. The handles' position could be adjusted so that when grasping the handle the participant's elbow could be aligned with the axis of rotation. A potentiometer was attached to the lower end of the axis to record the position of the lever. The output was sampled at 1000 Hz and stored on a computer for later analysis. A wooden board was placed over the table to prevent participants from seeing the lever and their arm. A video projector (temporal resolution 100 Hz; spatial resolution 1152 x 854 pixel), located behind the participants, was used to display the target pattern and feedback on the wall facing the participant. Feedback was provided by superimposing the target sequence pattern over the actual pattern produced by the participant (see Figure 1). In addition, the root mean square error indicating the difference between the target trajectory and the actual produced trajectory by the lever/limb system was provided to the participant, and presented on top of the pattern. Participants were told to attempt to reduce this error value from trial to trial. Participants were seated at about 2 meters from the wall and a 2 x 2 m image was projected on the wall. The cursor and the target were generated with custom software.

Insert Figure 1 about here

Experimental groups, task and procedure

After entering the laboratory young and older participants were randomly assigned to one of two practice conditions that differed in terms of the time to produce the movement sequence. All participants were informed by written and verbal instructions how to perform the task. One practice condition allowed the participant to perform the movement sequence in 1300 ms while the other condition permitted an additional 700 ms to perform the sequence (2000 ms). Participants were seated on a height-adjustable chair facing the wall and the apparatus was adjusted so that the participants had a comfortable position. At the starting position, the lower arm lever was positioned so that the upper-arm/lower-arm angle was approximately 85°. The participant's task was to move the lever through a sequence of elbow extension–flexion movements in the horizontal plane, in an attempt to produce the target spatial–temporal pattern displayed in front of them on the wall. The spatial–temporal sequence pattern was created by summing two sine waves with different amplitudes. The maximum amplitude in the target pattern was 45° from the start position (see Figure 1). One second after positioning the cursor in the start position (1°×1° box), a tone indicated to the participant to begin his/her response when he/she was ready. Data collection was started by the movement of the lever. If the participant moved from the start position prior to presentation of the tone, the participant was required to return to the start position before the tone was presented again. This insured that participants started from the same position (85° elbow angle), but could initiate their response when they felt ready. As soon as the participant started moving the target pattern and the start position box disappeared from the screen and a cursor representing the current position of the lever/arm was displayed. The participants were instructed to move the lever with their dominant right arm through the sequential pattern of extension–flexion movements (3 reversals; changing the movement direction from extension to flexion and vice versa) in an attempt to produce the target spatial–temporal pattern as accurately as possible in a continuous manner. Note that the target pattern was displayed prior to the movement, but it was removed at movement onset. Approximately 10 s following the completion of the participants' response, feedback was provided for 5 s. For each trial the potentiometer output was recorded for 2000 ms for the 1300 ms condition and for 2500 ms for the 2000 ms condition. Practice of the target waveform consisted of 11 blocks of 9 trials. Retention performance was assessed approximately 24 hrs following practice. The retention test consisted of 9 trials of the practiced sequence without feedback. Note that with the exception that feedback was not provided, all other conditions stayed the same as during the acquisition phase. Following the retention test the cognitive status for all participants was assessed by the Montreal Cognitive Assessment (MoCA) a cognitive screening tool with superior sensitivity indicating the cognitive decline in normal aging which also evaluated the participants working memory capacity (Nasreddine et al., 2005).

Data analysis and statistics

Data was analyzed using Matlab (Mathworks, Natick, MA, 2017a). The individual trial time series was used to compute lever displacement. To reduce noise the angular displacement time series were filtered with a 2^{nd} order dual-pass Butterworth filter with a cutoff frequency of 10 Hz. The primary overall error measure was the root mean square error (RMSE), computed between the angular elbow extension-flexion sequence and the target trajectory. RMSE captures errors in amplitude and time. Values of RMSE for individual trials were then averaged for each participant to yield a global estimate of RMSE for each block (9 trials). In addition, to assess whether practice improved the processing of temporal and spatial accuracy of the movement production, error measures in scaling the timing and amplitude were computed, using point estimates at the three peaks of the target pattern as a reference. The error measure was the absolute constant error (ACE). The ACE is an estimate of the accuracy with which the produced movement was scaled in time (ACE timing) and amplitude (ACE amplitude) as spatial accuracy. ACE was calculated as the absolute difference in time or amplitude at the Peaks 1 to 3 between the target and the produced sequence pattern. The values of each Peak for individual trials were then averaged for each participant to yield a global estimate of ACE timing and ACE amplitude for each block (9 trials). A supplementary measure was the index of harmonicity (H). This measure is based on the angular kinematics of the elbow acceleration obtained by the second derivation of the angular displacement of the elbow extension-flexion sequence. The H-value was computed as an indicator for cyclical, continuous or discrete movements and indicated the presence of goal-directedness of the continuous movement where a harmonic motion is required to achieve spatial-temporal accuracy (Guiard, 1993; Kovacs, Han, & Shea, 2009). Windows between a pair of zero crossings in the displacement trace are defined in order to compute an index of movement harmonicity (Guiard, 1993). Each non-overlapping time window comprises a single movement reversal. Within each time window, all deflections of the normalized acceleration trace are identified. When the acceleration trace is positive (negative displacement) within this window, H is computed as the ratio of minimum to maximum acceleration. Conversely, when the acceleration trace is negative (positive displacement) within this time window, H is computed as the absolute ratio of maximum to minimum acceleration. When a single peak (sinusoidal acceleration) occurs in the acceleration trace within this window the value of H is set to 1, indicating harmonic and continuous motion of the limb. If the acceleration trace crosses from positive to negative (or vice versa) within this window, the value of H is set to 0, indicating inharmonic and discrete motion. Finally, the individual H-values of each time window for a trial are averaged yielding a global estimate of H. Following this, the H-value for individual trials was then averaged for each participant to yield a mean H-value for each block (9 trials). In order to assess if the cognitive status is involved in the development and maintenance of sequence performance, the MoCA scores were correlated with the RMSE.

Statistical analyses were computed with SPSS for Windows version 22.0 (IBM Corp., Armonk, NY, USA). The analyses of variance (ANOVA) were computed using the

Greenhouse-Geisser corrections when the epsilon value was smaller than 1 (Greenhouse & Geisser, 1959). The effect size partial eta square (η_p^2) was determined for all significant effects (Cohen, 1988). Significant main effects and interaction effects were followed by simple main effect analysis. The correlations were calculated by the Spearman Rho procedure. The mean RMSE and the H-value in acquisition were analyzed with a 2 (Age: young adults, older adults) x 2 (Acquisition condition: 1300 ms, 2000 ms) x 11 (Block: 1 - 11) ANOVA with repeated measures on Block. Retention data were analyzed with a 2 (Age: young adults, older adults) x 2 (Acquisition condition: 1300 ms, 2000 ms) ANOVA. In addition, retention performance of the ACE timing and the ACE amplitude were analyzed in a 2 (Age: young adults, older adults) x 2 (Acquisition condition: 1300 ms, 2000 ms) x 3 (Peak: 1 - 3) ANOVA with repeated measure on Peak. The analysis of the H-value was conducted to determine if there was evidence of participants performing the sequence with more inharmonic or harmonic motion. Note that lower values of H indicate the tendency to perform the sequence with an inharmonic motion. To determine that the MoCA scores between the 1300 ms and the 2000 ms condition did not differ for both age groups a Mann-Whitney-U-Test was computed. On the retention test a separate correlation was computed across the young adults and the older adults between the MoCA scores and the RMSEs to determine the co-variation between the cognitive status and retention performance of the movement sequence.

Results

Figures 2A and 2B display the acquisition and retention results of the RMSE, and Figures 3A and 3B the corresponding H-values. Figure 4 shows the correlations between the RMSE and the MoCA score from the young and the older adults.

Insert Figure 2A and 2B about here

Acquisition

RMSE: The analysis of the RMSE detected main effects of Block, $F(10,520) = 94.32$, $p < .0001$, $\eta_p^2 = .65$, Acquisition condition, $F(1,52) = 8.67$, $p < .01$, $\eta_p^2 = .14$, and Age, $F(1,52) = 21.47$, $p < .0001$, $\eta_p^2 = .29$. Duncan's new multiple range test indicated that the RMSE decreased through Block 7. No further differences were detected for Blocks 8 – 11. The main effect of Acquisition condition indicated that RMSE was larger for the 1300 ms condition than for the 2000 ms condition. Older adults showed a larger RMSE compared to the young adults. The Age x Acquisition interaction, $F(1,52) = .79$, $p > .05$, and all other statistical analysis failed to reach significance.

Insert Figure 3A and 3B about here

H-value: The analysis of the H-value indicated a Block x Acquisition condition interaction, $F(10,520) = 2.77$, $p < .05$, $\eta_p^2 = .05$. Simple main effect analysis for Block across Acquisition condition showed that the H-values were larger for the 1300 ms condition compared to the 2000 ms condition until Block 8. Then for both Acquisition conditions the H-values did not differ. The analysis also indicated main effects of Block, $F(10,520) = 30.94$, $p < .0001$, $\eta_p^2 = .37$, Acquisition condition, $F(1,52) = 13.51$, $p < .01$, $\eta_p^2 = .21$, and Age, $F(1,52) = 13.42$, $p < .01$, $\eta_p^2 = .20$. Older adults showed lower H-values than the young adults. All interactions failed to reach significance.

Retention test

RMSE: The analysis detected only a main effect of Age, $F(1,52) = 28.58$, $p < .0001$, $\eta_p^2 = .34$. The main effect of Acquisition condition and the interaction Age x Acquisition condition failed to reach significance. The older adults produced a larger RMSE than the young adults.

H-value: The analysis indicated a main effect of Age, $F(1,52) = 10.59$, $p < .01$, $\eta_p^2 = .17$. The H-values were lower for the older adults compared to the young adults. All other statistical analysis failed to reach significance.

ACE timing: The analysis revealed a Peak x Age interaction, $F(2,104) = 5.50$, $p < .01$, $\eta_p^2 = .10$. Simple main effect analysis for Peak across Age indicated that older adults perform Peak 3 with larger timing errors compared to the young adults. For Peaks 1 and 2 the ACE timing did not differ between the two age groups. In addition the main effects Age, $F(1,52) = 4.20$, $p < .05$, $\eta_p^2 = .08$, and Peak, $F(2,104) = 13.47$, $p < .0001$, $\eta_p^2 = .21$, reached significance.

ACE amplitude: The analysis of the ACE amplitude indicated a Peak x Age interaction, $F(2,104) = 9.63$, $p < .0001$, $\eta_p^2 = .16$. Simple main effect analysis for Peak across Age indicated that older adults perform Peaks 1 and 2 with larger amplitude errors compared to young adults. For Peak 3 the ACE amplitude did not differ between the two age groups. The main effects Age, $F(1,52) = 22.55$, $p < .0001$, $\eta_p^2 = .31$, and Peak, $F(2,104) = 6.61$, $p < .01$, $\eta_p^2 = .11$, also reached significance.

Correlations RMSE and MoCA score

The MoCA scores between the 1300 ms and the 2000 ms conditions for the young participants, U = -.21, p >.05, and for the older participants, U = -.62, p >.05, indicated no significant differences. Note, one of the older participants refused to respond to the MoCA questionnaire. The RMSEs and the MoCA scores of the 1300 ms and the 2000 ms conditions were pooled before computing the correlations.

Insert Figure 4 about here

On the retention test the analysis showed a significant negative correlation between the RMSE and the MoCA score for the older adults, r = -.38, p < .05, $r^2 = .14$, but a near zero non-significant correlation for the young adults, r = .03, p > .05. This finding indicates that in older adults higher MoCA scores co-vary with lower RMSE.

Discussion

In the present experiment we compared young and older adults performing an extension-flexion sequence in 1300 ms or 2000 ms. Seidler and Stelmach (1995) showed that self-paced movement has the potential to cause performers to focus more on accuracy and others more on speed. Therefore, to increase the likelihood that performers emphasize accuracy, the task was predetermined in time to 1300 ms or 2000 ms. To determine the interaction between cognitive aging and motor learning, following the retention test the cognitive status of all participants was assessed by the MoCA. In terms of extended time to perform a movement sequence and aging we hypothesized that allowing additional time to produce the sequence of extension-flexion movements would facilitate movement accuracy especially for older adults and that sequence learning would be superior for older adults with a better cognitive status.

The acquisition results indicated that both age-groups reduced the RMSE during acquisition in both the 1300 ms and the 2000 ms conditions. This suggests that participants in both age-groups and Acquisition conditions improved during practice. However, both age-groups performed the 2000 ms condition with smaller errors, but older adults showed a larger RMSE compared to the young adults in both conditions. Considering the slowing down of the learning curve as a result of aging and that older adults started with larger RMSEs than young participants, the descriptive data for the young adults (mean decrease of -10.1°) and the older adults (mean decrease of -9.0°) from the beginning of acquisition (Block 1) to the end of acquisition (Block 11) for the 1300 ms condition, showed that both age groups decreased their errors on a similar level. For the 2000 ms Acquisition condition the decrease of the RMSE for the young adults was -7.9° and for the older adults -11.4°.

On the retention test young adults outperformed the older adults regardless of movement duration. This indicated that increasing response duration resulted in performance advantages for young and older adults during acquisition, but on the retention test performance differences between the 1300 ms and the 2000 ms conditions diminished for both age groups. The young adults performed the 1300 ms and 2000 ms sequences with less errors compared to the older adults. This finding is contrary to our initial extended time and accuracy hypothesis, but was consistent with a number of previous movement sequence learning experiments that found older adults produced larger errors in sequence execution and exhibited less learning of the movement sequence than young adults (e.g., Panzer et al., 2011; Shea et al., 2006; Verwey, 2010; Voelcker-Rehage, 2008). Solely, extending the time to increase the opportunity to use closed loop control processes to update the ongoing movement as indicated by Panzer et al. (2014), does not seem sufficient to improve sequence performance in older adults compared to young adults. The displayed visual information about the position of the cursor indicating the position of the limb during movement execution is not sufficient sensory information for the older adults to perform a more accurate movement sequence. This result is also consistent with previous findings in the aging research that demonstrated a decline in perceptual abilities in older adults (Li, Lindenberger, Hommel, Aschersleben, Prinz, & Baltes, 2004; Seidler, 2010).

The task used in the present experiment required the participants to perform spatial temporal patterns of 1300 ms or 2000 ms by an elbow extension-flexion task, with three movement reversals. It is important to note that the simple movement sequence used in the present experiment required fewer reversals than the multi-element movement sequence used in previous studies by Panzer et al. (2011) or Shea, and colleagues (2006). Therefore, chunking individual elements to subsequences to reduce information processing demands is not as important for the simple movement sequences as for more complex sequences (see Verwey, 2010). Furthermore, this task requires less time for continuous force control in the agonist and antagonist muscles during sequence execution compared to previous experiments where the multi-element task (Shea et al., 2006) or the force modulation task was used (Voelcker-Rehage & Alberts, 2005). Even though the number of reversals in the sequence and the information processing demands such as chunking were reduced, the older adults showed less sequence learning compared to the young adults.

The analysis of the H-values (harmonicity) provided some additional insights. As expected during acquisition, the H-values for the 2000 ms condition were lower than for the 1300 ms condition regardless of age. The lower H-values of the longer duration movement sequence indicated that participants attempted more on-line control while executing the movement pattern. Note that lower H-values were typically found in on-line controlled movements and higher H-values in pre-planned movements (Shea, Kovacs, & Panzer, 2011). This finding is in accordance with previous empirical findings including only young adults (Kovacs, Boyle, Gruetzmacher, & Shea, 2010; Leinen, Shea, & Panzer, 2015), and it is consistent with the theoretical assumption of the planning and control framework proposed by Glover (2004). Therefore, pre-planning determines the initial movement parameters (kinematic characteristics of the movement) including timing and velocity, whereas the on-line control system monitors and if necessary adjusts movement progress ‘in flight’. According to Glover (2004), on-line adjustments are limited to the spatial characteristics of the movement. With increasing movement time the initial pre-planned component is gradually taken over by the on-line control processes. Both age groups tended to an on-line control mode, when the response time was extended.

Similar to the RMSE the H-values on the retention test differed between the older adults and the young adults. This indicates that older adults performed the 1300 ms sequence and the 2000 ms sequence in a less harmonic and continuous motion compared to the young adults. According to the planning and control framework (Glover, 2004), and the empirical findings from Kovacs et al. (2010) it seems that older adults differ in the use of a pre-planning mode, where movement parameters including timing and velocity are set-up in advance, and in the on-line control mode (see Leinen et al., 2015; Seidler & Stelmach, 1995; Shea et al., 2011) compared to young adults. Especially the H-value for the older adults at the 2000 ms sequence tended to 0.5. This is typically the point at which movements change from continuous towards discrete movements (Buchanan, Park, & Shea, 2006). This indicated that older adults decelerate and accelerate the movement at some point during sequence execution, which results in movement instability rather than in reducing performance errors.

With regard to the ACE amplitude older adults showed less spatial accuracy at the retention test at Peak 1 and 2 for the 1300 ms and the 2000 ms sequence compared to young adults. At Peak 3 both age groups did not differ. This finding suggest that spatial accuracy suffered at the beginning of the sequence where the pre-planning mode is primarily responsible to control the sequence independent of the extended time to perform the movement. With this additional analysis we can more precisely discuss the previous mentioned point about the insufficient external visual information of the position of the limb during movement execution provided by the cursor in respect of time periods during sequence execution. It seems that external visual information about the position of the limb/lever provided by the cursor and intrinsic proprioceptive information in both Acquisition conditions are sufficient enough for the older adults to increase spatial accuracy at the end of sequence execution (Glover, 2004), but not at the beginning. Note the target template in the 1300 ms and the 2000 ms conditions was exactly the same except that the template was of a longer duration in the 2000 ms condition.

The results outlined above are consistent with two lines of previous research: research of pointing movements and research of advanced action planning and working memory. According to the research of pointing movements, Dounskaia, Wisleder, and Johnson (2005) reported that delays in the acceleration profiles in reciprocal movements (reversal pointing movements without dwelling on the targets) are associated with difficulty to adequately tune the muscle activation pattern (see also Dounskaia, 2005). Note that in the Dounskaia et al. (2005) experiment young participants had to control one or two degrees of freedom movements to reach the target. The present findings suggested that older adults have difficulties tuning in the neuromuscular system for spatial accuracy at the beginning of sequence production independent of the extended execution time, and when they have to control only one degree of freedom. However, later during sequence execution the spatial accuracy between young and older adults did not differ, while accuracy in timing increased between both age groups during response execution. This result is in agreement with the pre-planning on-line control idea from Glover (2004) who proposed that on-line adjustments are limited to the spatial characteristics of the movement. However, the current results are also consistent with findings from Ketcham, Dounskaia, and Stelmach (2004) that older adults have problems to control simultaneously different mechanical/kinematic components of a movement.

As observed from advanced action planning and working memory research, older adults segment movements into shorter sub-movements to reduce the load of the working memory (see also Bo et al., 2009; Seidler & Stelmach, 1995). Theoretical discussions of the control processes in perceptual-motor tasks have suggested that the reliance on feedback is due to a 'play-it-safe' strategy (Welsh et al., 2007). This means that older adults know that their motor system is not as reliable as at a younger age, and therefore they try to divide the movement into shorter sub-movements in order to plan an action and then use sources of feedback for closed loop control to ensure spatial accuracy. The results of the H-values for the older adults at the 1300 ms and the 2000 ms sequence suggest that older adults have difficulties to concatenate sub-movements (Cooke, Brown, & Cunningham, 1989), because concatenation of sub-movements would suggest that delays and/or adjustments would be minimized (Guiard, 1993; Shea, Panzer, & Kennedy, 2016). Whereas, a decline in sequence learning is not uncommon when older participants have to develop longer chunk patterns (Panzer et al., 2011; Shea et al., 2006; Verwey, 2010), the current experiment indicated that a decline in sequence learning with aging also occurred when chunking processes are less important to perform the task. The MoCA data also support this notion.

The median MoCA score for the older adults was 27 and for the young adults 28 (see also Table 1 for more detailed information). This indicates that the average cognitive status for the older adults was above the threshold of 26 of normative data for cognitive impairment (Kenny, Coen, Frewen, Donoghue, Cronin, & Savva, 2013). The negative correlation for the older adults between the MoCA scores and the RMSE on the retention test that we observed, suggests that older adults with a better cognitive status showed superior performance in sequence execution. This finding is consistent with our initial hypothesis. While the MoCA is a relatively simple screening tool for the cognitive status including attention, working-memory, executive functioning and visual-spatial ability, the present results are in line with other findings that reported that a decline in cognitive functioning is associated with a decline in movement sequence learning (see Bo et al., 2009; Salthouse, 1996; Voelcker-Rehage, 2008), and that there is a close interaction between deficits in motor learning and cognitive aging (Cai et al., 2014).

In conclusion, slowing the movement by extending the time to produce a continuous movement sequence improved the acquisition performance, but did not facilitate sequence learning in older adults compared to young adults. With regard to the ACE amplitude, older adults exhibited less control in managing spatial accuracy of initial sequence execution (Rabbitt, 1979) independent of the extended time to perform the sequence. Furthermore, the negative correlation between the RMSE and the MoCA scores suggests that the cognitive status predicts sequence learning, and that cognitive aging is involved in some of the regressive processes in motor sequence learning of older adults. Although in the current task participants have to control only one degree of freedom the task requires some continuous proprioceptive and visual control for the 1300 ms or 2000 ms sequence. However, performance of the older adults suffers. In the current experiment proprioceptive information was not inhibited, but visual information was limited to a cursor indication the position of the limb. Indeed, it seems possible that providing more visual feedback about the task is more important than proprioceptive feedback to improve performance (Nemanich & Earhart, 2015) in older adults. Future studies should focus their attention on systematically manipulating visual information such as providing concurrent visual information about the target and the position of the limb to increase closed loop control in older adults. If concurrent visual information improves performance of such simple one degree movements in older adults more complex movements where more degrees of freedom must be controlled should be tested.

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Compliance with Ethical Standards:

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The first author declares that she has no conflict of interest.

The second author declares that he has no conflict of interest.

The third author declares that he has no conflict of interest.

The fourth author declares that he has no conflict of interest.

The fifth author declares that he has no conflict of interest.

All procedures performed in the current experiment were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study.

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Figure captions

Figure 1. Schematic illustration of the apparatus with a participant sitting in front of the table, and the target sequence pattern, the produced sequence pattern and the RMSE displayed on the wall. Note, during the experiment the limb was covered symbolized by the transparent rectangle.

Figure 2. In Figure 2 (A) are the mean RMSEs and the standard error of the means (SEMs) of the acquisition phase for the older adults (OA) and the young adults (YA) at the 1300 ms and the 2000 ms conditions displayed. Figure 2 (B) illustrated the mean RMSEs and the SEMs of the retention tests for the older adults and the young adults at the 1300 ms and the 2000 ms conditions.

Figure 3. In Figure 3 (A) are the mean H-values and the SEMs of the acquisition phase for the older adults (OA) and the young adults (YA) at the 1300 ms and the 2000 ms conditions displayed. Figure 3 (B) illustrated the mean H-values and the SEMs of the retention tests for the older adults and the young adults at the 1300 ms and the 2000 ms conditions.

Figure 4. Figure 4 illustrated the scatter plot of the RMSEs and the MoCA scores of the older adults (black dots) and the young adults (grey dots). The black line represents the linear regression slope of the older adults, and the grey line the regression slope of the young adults.

Figure 1

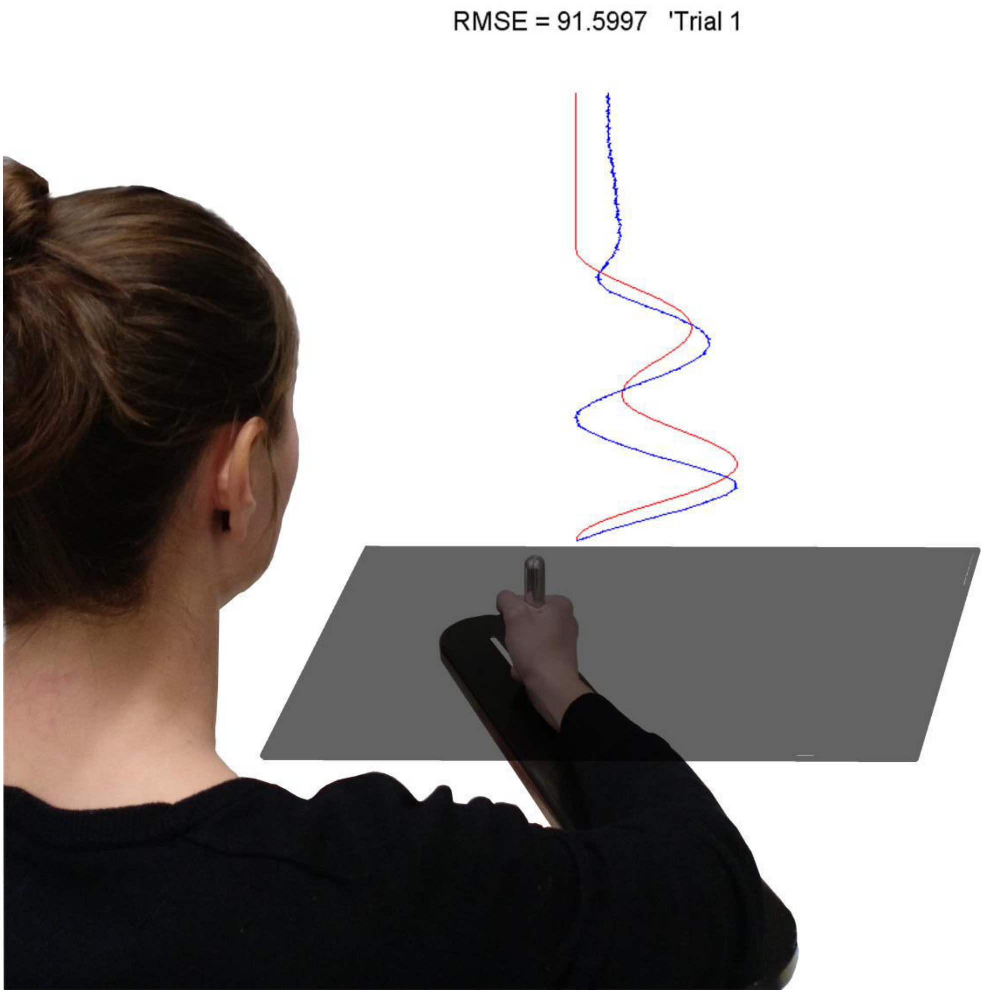

Figure 2

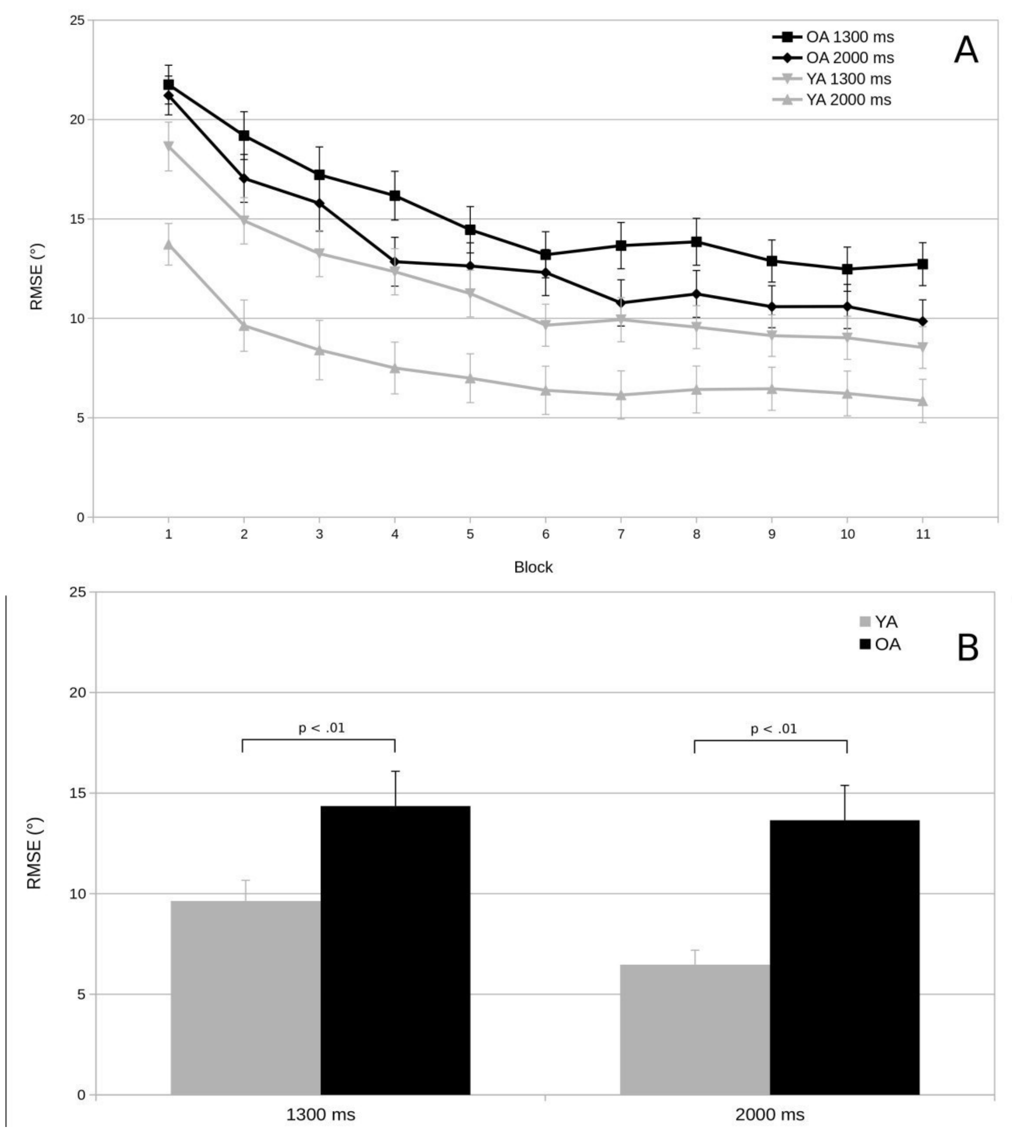
A
OA 1300 ms
OA 2000 ms
YA 1300 ms
YA 2000 ms
RMSE (°)
Block
B
YA
OA
p < .01
p < .01
RMSE (°)
1300 ms
2000 ms

Figure 3

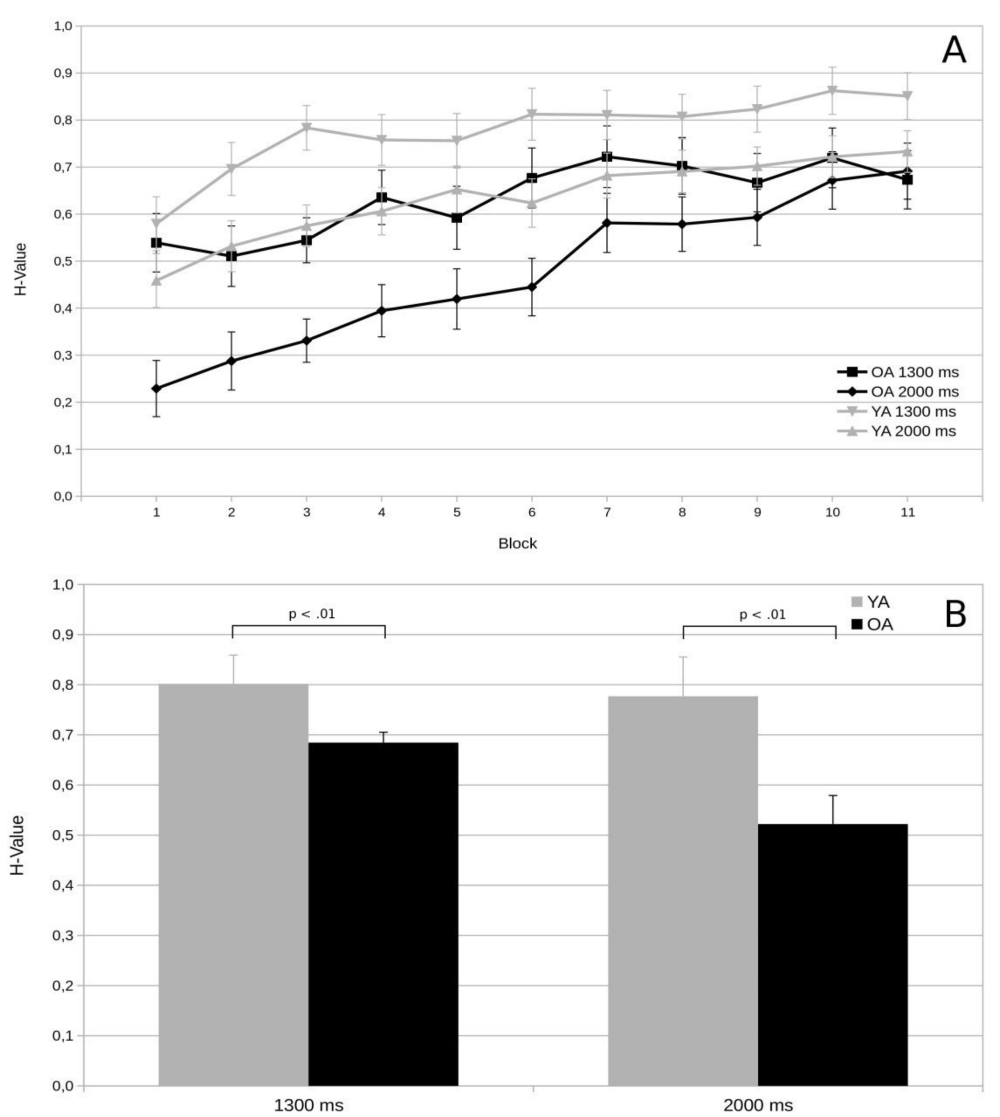
A
H-Value
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
1
2
3
4
5
6
7
8
9
10
11
Block
OA 1300 ms
OA 2000 ms
YA 1300 ms
YA 2000 ms
B
YA
OA
p < .01
p < .01
H-Value
1300 ms
2000 ms

Figure 4

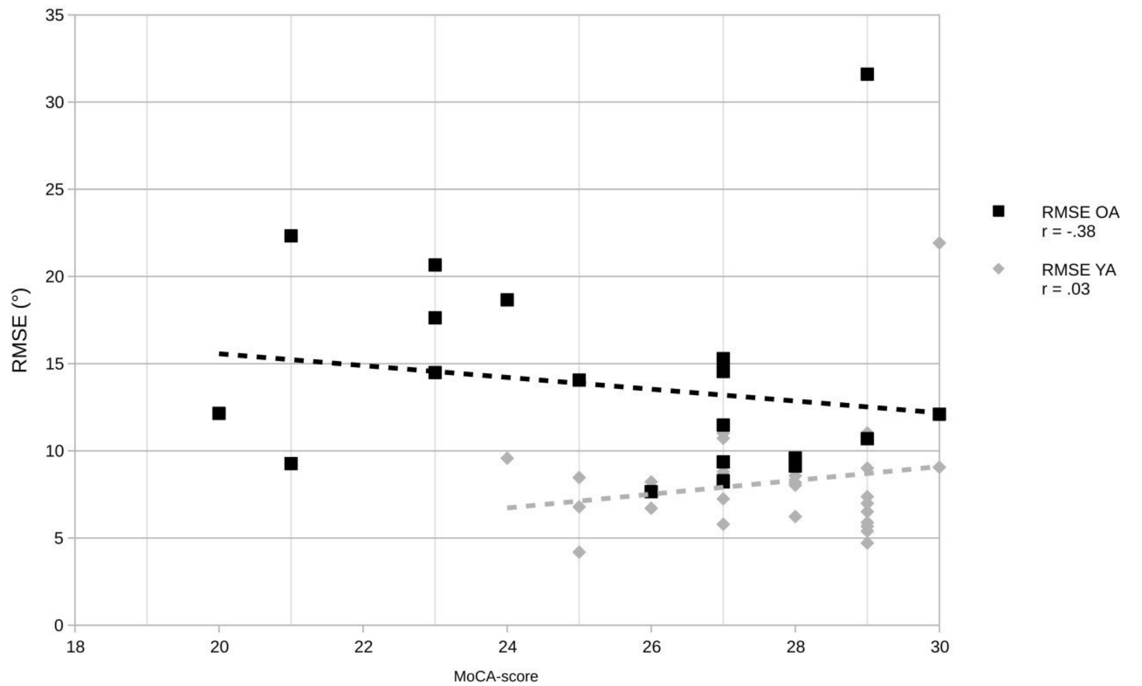
35
30
25
20
15
10
5
0
RMSE (°)
18
20
22
24
26
28
30
MoCA-score
RMSE OA
r = -.38
RMSE YA
r = .03

Table 1: Characteristics of the participants of the different groups (means, SD, for age and median and interquartile range for the MoCA score).

Group	Number of participants	age (years)	female/male	MoCA scores
YA 1300 ms	14	20.71 (1.77)	6/8	27.5 (2)
YA 2000 ms	14	21.71 (2.67)	6/8	28.0 (3)
OA 1300 ms	14	70.28 (4.63)	6/8	26.0 (5)
OA 2000 ms	14	70.31 (3.15)	8/6	27.0 (5)

Eidesstattliche Versicherung

Ich versichere, dass ich die eingereichte kumulative Dissertation selbstständig, ohne unzulässige fremde Hilfe und ohne Benutzung anderer als der angegebenen Quellen und Hilfsmittel angefertigt und die den benutzten Werken wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht habe. Zudem versichere ich, dass die Dissertation in dieser oder ähnlicher Form noch nicht anderweitig als Promotionsleistung vorgelegt und bewertet wurde.

Saarbrücken, den 02. März 2022

Janine Vieweg