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The Effects of Stimulus Complexity and Timing during Dual Task across Neurologically- Healthy Older and Younger Adults: A Pilot Study

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Abstract

Dual task protocols are often used to assess the simultaneous performance of two tasks. However, the cognitive and perceptual load factors of empirically studied dual tasks often vary considerably. Thus, the current pilot study systematically investigated the effects of dual task constraints across varying levels of complexity, for three groups of neurologically healthy adults, by closely manipulating cognitive and perceptual load factors. Using a novel methodology, performance was measured during both simple and complex dual tasks that were systematically varied according to stimulus onset asynchrony and set size. The results revealed that set-size and stimulus onset asynchrony factors interact to significantly increase levels of dual task interference. The implications of key findings and potential future applications for this novel dual task protocol are further discussed.

Keywords: Dual task; Aging; Cognitive load; Perceptual load; Interference; Stimulus onset asynchrony

Introduction

The effect of cognitive aging on dual task behaviors is well described [1, 2]. When two tasks are performed concurrently, older adults' responses tend to slow or become less accurate than younger adults' affecting performance in one or both tasks [3]. This dual task cost and its associated pattern of interference is assumed to be due to an age-related reduction in attention processing capacities [4,5]. A number of different dual task approaches are commonly employed to quantify interference effects, many of which involve complex tasks (i.e. tasks involving a large number of discrete cognitive operations) or which are performed concurrently with another task [6-10]. As has been noted by Hartley [11], sources of interference are not always fully controlled since cognitive operations may overlap across tasks in unexpected ways. It is therefore uncertain whether decrements in task performance associated with healthy aging under such conditions, are task specific or generalized [11].

An alternate approach is to employ concurrent tasks that require fewer operations to manipulate the timing and degree to which two tasks overlap [5,9,12-16]. Thus, by reducing the onset time of one task (or stimulus onset asynchrony) in relation to the second task, responses are slowed due to increased levels of competition for a single response channel or by higher levels of competition for shared cognitive resources [5]. This interference latency is known as the Psychological Refractory Period (PRP) [5,9]. According to Pashler [5] and others [9,12,17], this phenomenon may be due to a combination of stimulus asynchrony and the temporal uncertainty [5,9,12,17] requiring vigilance and potential anticipatory priming [6]. PRP is an approach that has not only revealed reliable interference effects associated with cognitive aging, but has also provided information on causes and progression of dual task interference. For example, Hartley [11], used a PRP paradigm that varied input and output modalities across a series of dual task experiments, and demonstrated reliable effects of interference in both younger and older adults. In particular, interference effects were observed for both age groups for dual task conditions in which both tasks shared the same input/perceptual modality, as well as, when the task responses shared the same output/response modality. In contrast, age-related effects were limited to the planning, programing, and execution of responses. However in another more recent study, cross-modal effects were observed by Hein and Schubert [18] for older adults when the visual and auditory input stimuli were highly salient, through modification of stimulus intensity, showing a condition in which aging affects can occur. This line of research is significant in that it indicates dual task interference and additive effects of aging are also associated with complexity effects at both perceptual and response-generation levels. These implications have been exploited in a PRP dual task training paradigm by Bherer and colleagues[19], who have demonstrated cognitive gains and generalization behaviors for older adults subsequent to a training epoch [19,20].

Current study

Thus, while it is clear that dual task costs are exaggerated by aging and apparently closely associated with response-generation processes, it remains untested as to whether interference, through the manipulation of cognitive and perceptual load factors, or aging effects also appear at the level of response-planning and are subject to complexity effects. Of particular interest is the interaction of SOA, stimulus modality, and stimulus complexity with an age factor. While it is known that dual task effects are independently associated with SOA, stimulus modality and stimulus complexity factors across studies [7,11,18-20], it is not known how these factors interact across the lifespan. For example, it appears that dual task effects of stimulus modality and advanced old age are most apparent at perceptual stages of processing [7]. Thus, interactions may elucidate the organization of load factors supporting dual task interference under conditions in which response competition for generation is controlled. In this study, a PRP paradigm was included which consisted of 2 simple competing go-no-go tasks. In one task, participants manually responded to a target visual stimulus and in the rival task participants responded to a target auditory stimulus. Importantly, all visual and auditory stimuli were abstractions, that is – simple, unfamiliar non-geometric shapes selected from a prior study investigating visual image salience and pure tones with limit to linguistic labeling [21]. Using a novel methodology, performance was measured during both simple and complex dual tasks that were systematically varied according to SOA and stimulus set size.

The dual tasks were presented in a trial structure without competition with regard to the modality of manual response, since in each trial a manual response was required for either a visual or an auditory target, i.e. a single manual response per trail. Task onsets per trial and stimulus order were pseudo-randomized to 300, 600 or 900ms SOA. A separate dual task experiment was provided in which the complexity of both the visual and auditory stimuli varied according to set size, (i.e. rather than responding to a single tone, participants responded to a non-musical sequence of tones).

Thus in accordance with the literature cited above [7,11,18-20], both perceptual and response-generation conditions were carefully controlled to prioritize source interference effects to response-planning levels. Since our PRP paradigm controlled for perceptual demands by presenting cross-modal stimuli with low salience, and response-generation demands using a single manual response channel without competition, it was hypothesized that any dual task interference would be at the level of response-planning rather at the levels of perceptual processing or response-generation. Our specific aims were as follows:

Aim 1: To test whether stimulus complexity and processing modality will differentially affect cognitive load. Our hypothesis predicted that changes in cognitive function (reaction time, accuracy) due to increased cognitive load (modality and stimuli complexity) during dual task would show differences in processing demands at the level of stimulus complexity independent of processing modality (auditory and visual).

Aim 2: To test whether stimulus complexity and processing modality would differently affect age groups. Our hypothesis predicted that age groups (Group 1=18-30 years old), (Group 2=31-54), and (Groups 3=55-80 years old) would demonstrate different cognitive load characteristics due to stimulus and modality levels. We hypothesized that participants would demonstrate decreased cognitive performance (increased reaction time and decreased accuracy) with increased stimulus complexity and increased difficulty in modality conditions.

Method

Participants

Thirty-seven native speakers of American English (Male=9, Female=28), 18-80 year of age, participated in all tasks. Participants were divided into three groups based upon age. Group 1 included 12 individuals 18-30 years old (Mean=22.75, SD 2.30). Group 2 consisted of 14 individuals 31-54 years old (Mean=45.5, SD 7.56). Group 3 was comprised of 11 individuals 55-80 years old (Mean=62.82, SD 7.08). All participants completed a brief cognitive, handedness, vision, and hearing discrimination screening in a quiet room free from other distraction. Cognitive function was screened using the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MOCA). Participants were required to meet a raw score of 23 or greater on the MMSE or a raw score of 26 or greater on the MOCA. Since the experimental task involved bimanual responding, the Edinburgh Handedness Inventory was used to profile handedness [22]. Scores of 40 or greater indicated right handed dominance. The vision screen included individuals identified shapes and letters presented on a 15 inch flat screen monitor in a black font against a white background. Inclusion criterion for the Vision Screen was a score of 90% or greater.

The hearing discrimination screen required individuals to verbally respond to and discriminate between high, low and mid-range pure tones that were presented auditorily through an audiometer at a standard intensity of 65 dB. Inclusion criterion for the Hearing Screen was a score of 90% or greater. Three individuals voluntarily declined to complete the study and were therefore excluded. This project was approved by the Institutional Review Boards at Illinois State University and Midwestern University. Informed-consent was given by all participants in this project.

Materials and Procedure

General description of task conditions

Materials: During Participants wore high quality stereo headphones adjusted to the sound level that was "most optimal and comfortable" for them while viewing pictures presented on a 23-inch monitor. Participants were verbally instructed to use the furthermost right and left buttons on a DirectIN high speed button-box, within an array of 9 buttons (Empirisoft). Participants were verbally instructed to press and release the left button with their left index finger when they registered a target visual stimulus and the right button with their right index finger when they registered a target tone across simple and complex runs.

Auditory: stimuli and procedure

Auditory stimuli: Auditory stimuli consisted of six target pure tones and twelve foil pure tones each with a duration of 750 ms. Tones were generated using Adobe Premiere Elements 11, in accordance with protocols developed by Burton et al. [23], LoCasto et al. [24], and Cuellar et al. [25]. To ensure that the pure tones were also perceived as maximally discriminable, all tones (500, 750, 1000, 1250, 1500, 1750, 2000, 2500, 2750, 3000, 3250, 3500 Hz) were separated by a minimum of 250 Hz [24]. Additionally, all tones were randomized in the 18 auditory stimuli.

Auditory procedure: During the auditory task procedure, participants were verbally instructed to listen to different tones and press and release the right button with their right index finger when they registered the target tone.

Visual: stimuli and procedure

Visual stimuli: The visual stimuli were pictures, consisting of 18 black and white abstract shapes, which were reproduced and selected with permission from Paller and Voss [26]. Six target visual stimuli and 12 foil visual stimuli that were perceived as 'maximally visually discriminable' by five blinded judges were selected for inclusion. In an attempt to minimize potential lexical-semantic priming bias associated with the use of covert naming, all of the visual stimuli selected were taken from the 'low meaning' conceptual category of line drawings, as normed by Voss, Schendon, and Paller [24] (See Figure 1). For an example of the visual and auditory target and foil stimuli, see Figure 2 and Figure 3.

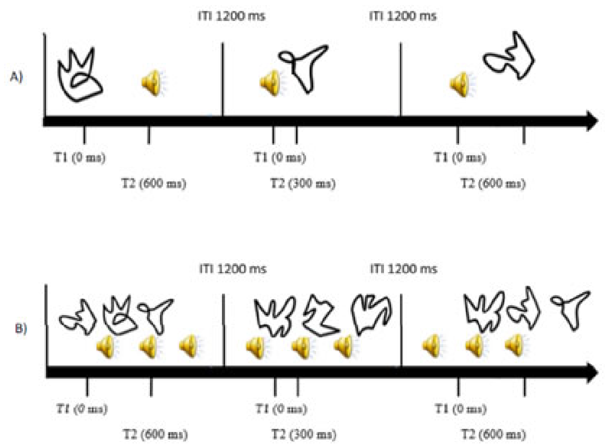

Figure 1: Row (A) Depicts a sample time course for the simple dual task condition and row (B) Depicts a sample time course for the complex dual task condition.

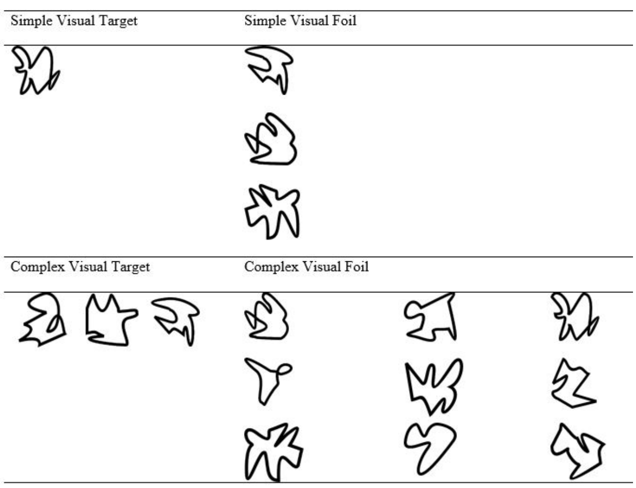

Figure 2: Example visual target and foil for simple and complex conditions.

Visual procedure: During the visual task, participants were asked to view the computer screen and press and release the left button with their left index finger when they registered a target abstract shape.

For both the simple and complex experimental conditions, 2600 ms. audio-visual movie clips were created using Adobe Premiere Elements 11, which were presented in continuous block runs via E-prime v2.0.

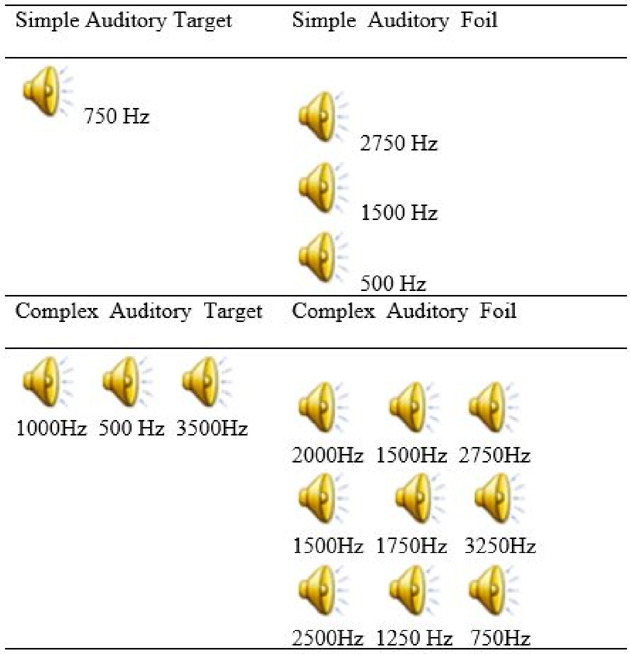

Figure 3: Example auditory target and foil for simple and complex conditions.

Practice protocol

Participants were provided with 16 practice trials for each experimental condition using the same stimulus materials and targets at a fixed SOA set to 600 ms to control for short term memory effects. Order of presentation for visual and auditory stimuli was counter balanced and pseudo-randomized across trials to ensure that the same number of auditory and visual targets presented as target 1 and target 2. All participants past the practice trials with greater than 90% accuracy in both simple and complex conditions indicating that both target auditory and visual stimuli were fully encoded prior to the initiation of block runs. Immediately following the practice trials, the experimental simple audio-visual dual task condition was administered.

Experimental conditions

There were two experimental conditions, a simple then complex condition, which consisted of 24 continuous trials, separated by 500 ms. Within each block run target stimuli and foils were randomized. Similar to the practice protocol, order of presentation for visual and auditory stimuli was counter balanced and pseudo-randomized across simple and complex condition runs to ensure that the same number of auditory and visual targets presented as target 1 and target 2.

Simple condition

The Simple condition included measures of processing speed, for visual and auditory modalities, and working memory for one target tone and one abstract image, in dual task. While simultaneously identifying the target abstract shape presented among various abstract shapes on a monitor, participants also heard pure tones (500, 750, 1000, 1250, 1500, 1750, 2000, 2500, 2750, 3000, 3250, 3500 Hz) in high quality stereo headphones and responded when a target tone was heard by pressing a button. Dependent measures included % correct auditory accuracy, % correct visual accuracy, Visual reaction Time (ms), Auditory reaction Time (ms). For the simple condition, each block run consisted of 24 trials, separated by 1200 ms. inter-trial intervals of no audio and blank white computer screens. Within each trial, stimuli onset times, i.e. the time that lapsed between the onset of the first stimuli presentation (T1) and the onset of the second stimuli presentation (T2), varied by 300, 600, or 900 ms., respectively. For example, a trial in the simple condition may begin with the presentation of a picture (T1) followed by a pure tone (T2) presentation, after a delay of 300 ms. All stimuli included in the simple condition, i.e. all pictures and pure tones, were presented for precisely 750 ms. During each block run of 24 trial presentations, 12 target visual (i.e. picture) and 12 auditory (i.e. pure tone) stimuli were presented four times at each level of stimuli onset asynchrony (SOA), 300 ms., 600 ms., and 900 ms. [27,28]. Likewise, 12 foil visual and auditory stimuli were presented four times across each level of SOA. All target and foil trial presentations were randomized during each block run. In order to analyze potential modality effects, 50% of the target and foil stimuli began with a presentation of visual stimuli and 50% began with auditory stimuli. The total experimental testing protocol lasted approximately 30 minutes.

Complex condition

The complex dual task included measures of processing speed, for visual and auditory modalities, and working memory for a set of three target tones and a set of three abstract images, in dual task. Procedures were identical to Experimental Condition A, however, single target shapes and tones were replaced with shape and tone sequences. While simultaneously identifying the target abstract shape set (3 abstract shapes) presented among various abstract shape sets on a monitor, participants also heard sets of pure tones (500, 750, 1000, 1250, 1500, 1750, 2000, 2500, 2750, 3000, 3250, 3500 Hz) on external computer speakers and responded when a target tone set was heard by pressing a button.

Dependent measures included % correct auditory accuracy, % correct visual accuracy, Visual reaction Time (ms), Auditory reaction Time (ms). The complex dual task condition included the same visual and auditory stimuli and SOA levels (i.e. 300 ms, 600 ms, and 900 ms) separating the onset of T1 from T2. However, the set size of visual and auditory stimuli increased to three. Thus, for the complex condition, three pictures were presented consecutively. The presentation of the three stimuli lasted for a total duration of 250 ms., each were presented in parallel. As with the simple condition, all picture and pure tone sequences lasted a total 750 ms in duration, each trial lasted 2600 ms in total duration, and each block run consisted of 24 trials.

The same parameters regarding the number of target and foil presentations across each SOA level, as well as the percent of trials beginning with visual vs. auditory stimuli, were applied to the creation of block runs for the complex condition.

All participants were tested in each of the 2 experimental conditions. Rest breaks were provided to participants following completion of each block run and between task conditions. During the experimental run, e-Prime presentation software recorded button responses for reaction time data in ms and accuracy data coded for accuracy as a binary variable. All experimental conditions and stimuli were counterbalanced. Additionally, auditory and visual stimuli were also randomly assigned.

Results

This study was a between-group 3 × 3 × 2 × 2 design with condition (Simple, Complex), SOA (300, 600, 900, and Modality (auditory, visual) included as the independent variables, and accuracy and reaction time as the dependent variables.

A Doubly Multivariate Repeated Measures Analysis, including Multivariate, Univariate, and Pairwise Comparisons, was conducted utilizing SPSS Statistics Version 22. The raw data is also included for reference, see Tables 1 and 2.

	Simple					
SOA	**Auditory Accuracy (%)**			**Visual Accuracy (%)**		
	Group 1	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
300	91.58% (SD=0.15)	91.57% (SD=0.14)	75.00% (SD=0.31)	90.25% (SD=0.13)	85.64% (SD=0.21)	78.2% (SD=0.29)
600	94.33% (SD=0.08)	91.14% (SD=0.16)	76.6% (SD=0.28)	87.33% (SD=0.14)	88.36% (SD=0.13)	84.9% (SD=0.25)
900	97.17% (SD=0.06)	88% (SD=0.12)	84.9% (SD=0.16)	95.75% (SD=0.07)	86.86% (SD=0.16)	73.4% (SD=0.29)
	Complex					
SOA	**Auditory Accuracy (%)**			**Visual Accuracy (%)**		
	Group 1	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
300	70.75% (SD=0.21)	64.71% (SD=0.16)	63.5% (SD=0.1)	72.25% (SD=0.14)	66.79% (SD=0.18)	66.6% (SD=0.22)

600	65.25% (SD=0.26)	60.64% (SD=0.19)	51.8% (SD=0.22)	65.17% (SD=0.25)	58.36% (SD=0.25)	55.1% (SD=0.22)
900	48.58% (SD=0.19)	38% (SD=0.15)	36.7% (SD=0.2)	40.25% (SD=0.13)	40.5% (SD=0.15)	35% (SD=0.19)

Table 1: Dual task accuracy average scores.

Simple						
SOA	**Auditory Reaction (ms)**			**Visual Reaction (ms)**		
	Group 1	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
300	844.43 (SD=154.38)	899.58 (SD=146.85)	909.07 (SD=177.41)	819.36 (SD=200.7)	895.69 (SD=100.39)	938.37 (SD=224.05)
600	956.08 (SD=144.8)	1023.13 (SD=167.91)	1011.43 (SD=125.21)	958.1 (SD=143.26)	977.44 (SD=152.45)	1124.44 (SD=209.26)
900	1104.49 (SD=134.89)	1142.51 (SD=136.92)	1106.74 (SD=235.4)	1080.47 (SD=170.43)	1111.14 (SD=159.1)	1192.39 (SD=170.92)
Complex						
SOA	**Auditory Reaction (ms)**			**Visual Reaction (ms)**		
	Group 1	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
300	1890.04 (SD=280.72)	1887.72 (SD=255.05)	1874.19 (SD=309.77)	1902.46 (SD=284.59)	2028.5 (SD=222.14)	1903.04 (SD=307.13)
600	1899.96 (SD=245.44)	1773.33 (SD=253.57)	1874.33 (SD=338.82)	2035.97 (SD=161.15)	2007.52 (SD=261.88)	2005.35 (SD=350.5)
900	1723.4 (SD=208.16)	1823.82 (SD=307.19)	1444.48 (SD=549.19)	1869.82 (SD=291.12)	1679.1 (SD=632.52)	1765.53 (SD=516.38)

Table 2: Dual task reaction time average scores.

Doubly repeated multivariate analysis

Statistical design was a 3 × 3 × 2 × 2 Doubly Multivariate Repeated Measures Analysis, including Multivariate, Univariate, and Pairwise Comparisons. The analysis was performed with Group (Group1: younger, Group 2: middle, Group 3: older), Condition (Simple, Complex), SOA (300, 600, 900), and Modality (auditory, visual), as factors with accuracy and reaction time as dependent variables. This analysis was utilized to account for multiple dependent variables, measured in different scales, with multiple administrations across time, and has been used when analyzing dual task methodologies [29,30].

Results revealed two omnibus effects with two interactions. There was a significant effect of Condition [Wilks' Lambda $F(2,32)=286.10$, $p=<0.000$, $\eta2=0.947$] and SOA [Wilks' Lambda $F(4,30)$ 24.64, $p=<0.000$, $\eta2=0.767$]. The Condition by SOA interaction [Wilks' Lambda $F(4,30)=22.27$, $p=<0.000$, $\eta2=0.748$] was significant. There was no significant omnibus effect of Group, Modality, Condition*Group, SOA*Group, Modality*Group, Condition*SOA*Group, Condition*Modality, Condition*Modality*Group, SOA*Modality, Modality*SOA*Group, Condition*SOA*Modality, and Condition*SOA*Modality*Group interaction.

Condition analysis

Univariate analyses were utilized to further investigate the effect of Condition across all levels of each additional factor (SOA and Modality). Significant main effects were found for Condition on accuracy measures [$F(1,33)=148.5$, $p=<0.001$ $\eta2=0.818$, (Greenhouse-Geisser Adjustment)], and reaction time measures [$F(1,33)=578.6$, $p=<0.001$ $\eta2=0.946$, (Greenhouse-Geisser Adjustment)]. The within-subject analyses are further explored below.

Condition analyses: Accuracy. Within subjects contrasts were conducted to further investigate the significant effect of Condition on Accuracy. Significant differences were found for Accuracy at Simple Condition and Complex Condition $F(1,33)=148.5$, $p=<0.001$ $\eta2=0.818$, (Greenhouse-Geisser Adjustment)]. Further examination of the main effects for Condition were completed using Pairwise Comparisons with Bonferroni corrections. All Pairwise Comparisons for Accuracy were found to be statistically significant ($p<0.001$). These differences suggest that participants are more accurate for the Simple Condition (M=0.867) when compared to the Complex Condition (M=0.556).

Condition analyses: Reaction Time. Additional within subjects contrasts were conducted to further explore the significant effect of

Condition on Reaction Time. Significant differences were found for Reaction Time at Simple and Complex Condition measures [$F(1,33)=578.6$, $p=<0.001$ $\eta 2=0.946$, (Greenhouse-Geisser Adjustment)]. Examination of the main effects for Condition were completed using Pairwise Comparisons with Bonferroni corrections. All Pairwise Comparisons for Reaction Time were found to be statistically significant ($p<0.001$). Inversely, compared to accuracy analyses, results indicate that participants were quicker in response for the Simple Condition (M=1010.32) than in the Complex Condition (M=1855.43).

Stimulus Onset Asynchrony (SOA) analyses

The effect of SOA across all levels of Condition and Modality were studied using univariate analyses. Results revealed significant main effects for SOA on Accuracy measures [$F(2,66)=29.29$, $p=<0.001$ $\eta 2=0.470$, (Greenhouse-Geisser Adjustment)] only. No effect was found for SOA on Reaction Time measures. The within-subject analyses for Accuracy are further explored below.

SOA analyses: Accuracy. To further investigate the significant effect of SOA on accuracy, within subject contrasts were performed. Significant differences were found for Accuracy at SOA 300 and 600 when compared to 900 $F(1,33)=76.01$, $p=<0.001$ $\eta 2=0.697$. Study of the main effects for SOA were completed using Pairwise Comparisons with Bonferroni corrections. All Pairwise Comparisons for Accuracy were found to be statistically significant ($p<0.001$) except one. The comparison of 300 SOA to 600 SOA was not significant. These differences indicate that participants were more accurate for the 300 SOA (M=0.764) when compared to the 900 SOA (M=0.638), and that participants were more accurate for 600 SOA (M=0.732) when compared to 900 SOA (M=0.638).

Interaction analyses: The Condition by SOA interaction was further explored using univariate analyses. Significant main effects were also shown for Condition by SOA interactions for Accuracy measures [$F(2,66)=36.88$, $p=<0.001$ $\eta 2=0.528$, (Greenhouse-Geisser Adjustment)], and Reaction Time measures [$F(2,66)=28.53$, $p=<0.001$ $\eta 2=0.464$, (Greenhouse-Geisser Adjustment)]. The within-subject analyses are further explored below.

Condition and SOA Interaction: Accuracy and reaction time. Within subjects contrasts were completed to further investigate the significant interaction between Condition and SOA. Significant differences were found for Accuracy and Reaction Time across all levels of Condition and SOA. As the task condition and SOA levels became more complex, performance decreased. Specifically, SOA at 300 and 600 appear to be significantly less challenging than SOA at 900.

Discussion

This study aimed to systematically examine the effects of dual task constraints across different levels of complexity, for three groups of neurologically healthy adults, by closely manipulating cognitive and perceptual load factors. Specifically, this study aimed to (1) test whether stimulus complexity and processing modality would differentially affect cognitive load, and (2) examine whether stimulus complexity and processing modality would differently affect age groups. The findings indicate the hypothesis for aim one was correct, study findings suggest that dual task complexity, manipulated by set size and SOA, significantly affects performance across neurologically healthy adults. While results suggest the hypothesis for aim two was correct, all participants' demonstrated significantly decreased cognitive performance with increased stimulus complexity and task modality, decline occurred regardless of age, with no significant difference between age groups. However, since the auditory and visual stimuli could be either target 1 (TI) or target 2 (T2) in the dual task, the findings of accuracy and reaction time are not purely due to the effects of stimulus modality. This potential for a stimulus modality confound should be considered in interpretation and discussion of findings. These data provide novel evidence that dual task interference, at the level of response-planning, are subject to complexity effects. Therefore, this preliminary data may provide additional insight into dual task processes in aging and how dual task methods may be manipulated for assessment and intervention of perceptual load factors.

Dual task complexity was manipulated through condition (simple, complex) and set size. The set sizes included one auditory and one visual stimulus (simple), and three auditory and three visual stimuli (complex). Unsurprisingly, participants were more accurate and faster when responding in the simple condition versus the complex. Because this was expected, and supports traditional dual task effects [31,32], the data offer evidence for a novel approach to studying dual task constraints by manipulating cognitive and perceptual load factors. Therefore, it may be the dual task interference of response-planning, not just response-generation that can be manipulated through dual task complexity. This additional understanding of complexity may inform clinicians in how they cognitively or perceptually load tasks during assessment or intervention.

SOA effects indicate that cognitive processing breakdown occurs between Simple and Complex dual tasks, as well as, between the 300 SOA/600 SOA and 900 SOA performances. In other words, for dual tasks that are challenging, adults across the lifespan may experience similar decline in performance. This finding suggests that the 900 SOA may requires increased levels of vigilance and potential anticipatory priming, thereby increasing cognitive load and working memory demands. This is a novel finding, performance decrements were greatest with increased separation of task onsets for both younger and older adults. We speculate that this is due to increased task demands associated with maintaining task vigilance for one target while also providing a manual response to another in close succession across different modalities. That is it may be that for this study and tasks response planning and response generation are operating in parallel, a process overlap, rather than in sequence at the longest SOA. In contrast, at the shorter SOAs response planning and response generation are operating in sequence. This is possible given the simplicity of the tasks used in this study. Interestingly, no effect was found for SOA on reaction times, suggesting that accuracy provided a more sensitive measure of interference in this particular paradigm. Further, the results indicate equivalent capacities across age groups, suggesting that in hierarchically complex dual tasks, age effects are either reduced or absent.

While age effects are well defined across dual task literature [2,20,33,34], these data indicate that as dual task complexity is hierarchically manipulated through increasing set size and SOA, performance is diminished regardless of age. These interference effects are occurring at the level of early and late processing. So, while some studies have shown that perceptual modality can be a source of interference under certain conditions; this was not the case here, which might imply that the source or level of interference is post perceptual. This is significant for older adults since perceptual systems and response systems slow particularly when put under high constraint.

This finding adds to knowledge of how multitasking performance changes as we age, wherein, if a multitasking activity, as is typical in activities of daily living, places too many cognitive and perceptual demands, adults will perform poorly overall. This insight may suggest that clinicians could modify or manipulate cognitive performance during intervention multitasking by varying not just set size, but when the stimuli sets are introduced, across patient age groups.

Clinical application

This preliminary project provides significant support for the use of a novel, dual task methodology that systematically manipulates complexity through set size and SOA levels. Initial findings suggest that in order to decrease mental fatigue during everyday life, individuals may also be able to purposefully manipulate response-planning to during intervention and activities of daily living. Ultimately, these individuals can learn to focus on completing one task at a time or train to complete a basic multi-tasking activity (two tasks that could easily be completed by themselves). However, this methodology and its applications warrant further investigation.

Future research

There is a broad consensus in the aging literature that the abilities to successfully multitask varies with advanced old age according to task, task complexity and other perceptual load factors. However, the relevance of these cognitive load processing competencies supporting dual task performance has not yet been empirically investigated to our knowledge. While this study has identified effects of load factors and combination independently of factor, it remains an open question whether the same pattern of robust graded interference effects holds or is further exaggerated by healthy aging. An extension of this line of research is to examine these load effects in relation to patient populations with altered frontal lobe function; in effect exploring pathological differences in cognitive architecture and adaptation. The potential future implications for this line of study is to further specify a sensitive methodological approach to quantifying effects of aging that is also and neuropathology useful to clinicians.

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