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The Impact of Motivation and Task Difficulty on Resource Engagement: Differential Influences on Cardiovascular Responses of Young and Older Adults

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Abstract

This study examined whether the level of cognitive engagement older adults were willing to invest is disproportionately influenced by the personal implications of the task, as suggested by Selective Engagement Theory. We experimentally altered the personal implications of the task by manipulating participants accountability for their performance. Young (*N* = 50) and older (*N* = 50) adults performed a memory-search task of moderate difficulty but within the capabilities of both age groups. Both physiological (systolic blood pressure responsivity; SBP-R) and subjective (NASA-TLX) measures of cognitive effort were assessed across all difficulty levels. The results replicated findings from previous research that indicated older adults must exert more effort than younger adults to achieve the same level of objective performance. Most importantly, our results showed that older adults were especially sensitive to our accountability manipulation, with the difference in SBP-R between accountability conditions being greater for older than for young adults. Finally, we found that there was little relation between subjective measures of workload and our physiological measures of task engagement. Together, the results of this study provide continued support for the Selective Engagement Theory.

Keywords

aging; cognition; motivation; cardiovascular; engagement; effort

Research in adult development is increasingly recognizing the importance of considering motivation in understanding aging and cognition, both as a reflection of adaptive functioning and as a determinant of age differences in performance (for reviews, see Hess & Emery, 2012; Mather & Carstensen, 2005). One perspective that has been use to characterize aging-related motivational processes is Selective Engagement Theory (SET; Hess, 2014). According to this framework, the costs of cognitive activity—as reflected in the effort associated with achieving an objective level of performance and associated fatigue—increase as one ages. This, in turn, is thought to influence older adults' motivation in two specific ways. First, it is hypothesized to result in a decrease in chronic motivation to engage in cognitively demanding activities, leading to declines in such activities in everyday life (e.g., Hess, Emery, & Neupert, 2012). Second—and of primary interest in the present study

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—age-related increases in costs are also hypothesized to result in increased situation-specific selectivity, with resource engagement being most probable in situations involving tasks of low self-relevance or with minimal personal implications.[1]

Support for this latter type of age-related selectivity has been obtained primarily from studies examining performance in relation to motivational manipulations designed to influence the perceived personal implications of the task (e.g., relevance of task to oneself, degree of personal accountability for performance). For cognitively demanding tasks in which age-related declines are typically observed (e.g., memory, attitude formation, emotion processing), older adults' performance is disproportionately benefited—and age differences attenuated—in situations where personal implications are great (e.g., Germain & Hess, 2007; Hess, Germain, Rosenberg, Leclerc, & Hodges, 2005; Hess, Germain, Swaim, & Osowski, 2009; Zhang, Fung, Stanley, Isaacowitz, & Ho, 2013). The inference from these findings is that the enhanced performance of older adults is related to selectively increased motivation to engage cognitive resources in support of performance. Whereas the data are consistent with the notion of selective engagement, the use of performance as an indicator of resource engagement is potentially problematic: although certainly correlated with engagement, it is at best an inexact measure (e.g., high engagement does not necessarily imply high levels of performance).

In the present study, we sought to examine age-related selective engagement of cognitive resources using a more direct and valid measure of resource engagement. In addition to the previously raised concern that many behavioral measures (e.g., performance, time on task) are problematic with respect to assessing resource engagement, an additional challenge relates to the degree to which a specific index can be used to make reasonable comparisons across age groups. For example, does the measure reflect the same underlying systems in young and old adults? Can responses be mapped onto a similar scale? One potentially viable measure is systolic blood pressure (SBP). Obrist's (1981) active coping model has argued that SBP response—that is, the increase in SBP above baseline (SBP-R)—is a relatively direct reflection of sympathetic nervous system response associated with active coping. Consistent with this idea, research integrating this model with motivational intensity theory (Brehm & Self, 1996) has shown that SBP-R in younger adults is systematically associated with subjective task difficulty when performance is perceived as both possible and worthwhile (for review, see Gendollla, Wright, & Richter, 2012). In other words, SBP-R is a measure of task engagement that reflects the degree of task difficulty, perceived capability to perform the task, and the motivation to do well.

With respect to the study of aging, research has suggested that SBP exhibits similar sensitivity to situations associated with active coping across adult age groups (for review, see Uchino, Birmingham, & Berg, 2010). In addition, unlike some other measures used to assess effort or engagement (e.g., pupillometric response, heart rate), Uchino et al. observed that the range of SBP reactivity to emotional tasks, including cognitive challenges, is relatively

[1]Selective Engagement Theory is complementary to the Selection, Optimization, and Compensation model (e.g., Baltes, 1997) in focusing on selection processes in the service of adaptive functioning. The latter, however, focuses more on global processes associated with organization of goal hierarchies, whereas selective engagement focuses more specifically on the impact of a specific mechanisms—costs of cognitive engagement—on chronic and situational motivation to engage in cognitively demanding activities.

stable, and may even increase, with age. Based on these and other considerations, Hess and Ennis (2014) argue that SBP-R is a reasonably valid index to not only assess cognitive engagement or effort in older adults, but also to make comparisons between age groups. Two recent studies have provided support for this assertion as well as for the assumption that the costs of cognitive engagement increase with age. Hess and Ennis (2012) found that older adults exerted more effort than young adults to support a fixed level of performance. In addition, sustained cognitive activity had greater fatigue costs for the older adults in that the relatively high levels of effort devoted to an initial task required older adults to exert even more effort to maintain performance in a subsequent task. Using a different task in which difficulty was systematically manipulated, Ennis, Hess, and Smith (2013) obtained similar results. Specifically, increased age was associated with greater levels of SBP-R at all levels of task difficulty, revealing again the increased effort necessary for older adults to achieve the same objective level of performance as younger adults.

The primary goal of the current research was to test a basic hypothesis of the selective engagement framework that, relative to younger adults, older adults' cognitive resource engagement is disproportionately influenced by the personal implications of the task. In contrast to the aforementioned previous tests of this hypothesis that used relatively indirect assessments of engagement, however, we used SBP-R as a more direct measure. Consistent with motivational intensity theory, research with younger adults observed that SBP-R is sensitive to the meaning attached to the task by the individual (see Gendolla et al., 2012). In the present study, we examined motivational influences using an accountability manipulation similar to ones used successfully in past research (e.g., Hess et al., 2009; Hess, Rosenberg, & Water, 2001). We predicted that, as the personal implications of the task are heightened by increasing public accountability (i.e., sharing performance results), two primary effects will be observed. First, SBP-R will increase in both young and older adults, reflecting greater engagement with higher accountability. Second, this effect will vary across age groups, with older adults exhibiting a disproportionately greater increase in engagement as accountability increased, reflecting the increased selectivity in resource engagement exercised in later life. Finally, these effects of accountability in the older group should increase in strength as the difficulty of the task—and associated costs—increase.

A secondary goal of the study was to further examine age differences in the costs of resource engagement using SBP-R. Employing a memory search task similar to that used by Ennis et al. (2013), we hypothesized that—as in that study—older adults would show higher SBP-R at all levels of task difficulty, reflecting the greater costs of cognitive engagement for older adults. We also predicted that SBP-R would increase over trial blocks due to fatigue; in other words, similar to physical activity, greater cognitive effort must be exerted to support performance as resources become depleted (e.g., Wright, Martin, & Bland, 2003; Wright, Stewart, & Barnett, 2008). We further predicted that this effect would be greater in older adults, once more reflecting the increased costs associated with engagement. As opposed to the Ennis et al. study, which used memory set sizes (i.e., difficulty levels) ranging from 2 to 10, we assessed performance only at task levels of moderate difficulty at which performance in both age groups was likely to be high and comparable. This decreased the probability of disengagement from the task due to high difficulty and allowed us to obtain a more precise measure of engagement in response to variations in cognitive demands that is unconfounded by performance. This, in turn, allowed a purer test of the idea that older adults would have to exert more effort than younger adults to achieve the same level of objective task performance.

Another goal was to explore the relationship between effort, as indexed by SBP-R, and subjective measures of workload. Of interest was the extent to which subjective assessments would be predictive of effort, and whether these subjective assessments would reflect the anticipated age differences in engagement across levels of task difficulty and motivation. To this end, we used the NASA-Task Load Index (TLX; Hart & Staveland, 1988) to assess the subjective costs of performance. The TLX is a widely used, reliable, and valid measure of subjective workload. There are several different possibilities regarding the relationships between SBP-R and TLX scores. First, subjective perceptions may be direct representations of the costs of cognitive engagement. (Note that we assume that, given its relationship to sympathetic nervous system activation, SBP-R represents energy expenditure at the physiological level.) That is, as participants put more effort into a task, they are aware of this and are able to make accurate judgments about their use of effort. A second possibility is that there are more subtle influences of costs that are not open to conscious awareness. Participants may not be cognizant of the amount of work they are putting forward, or the mapping of subjective perceptions onto physiological indices may be relatively imprecise. A final option is that other factors may moderate the perceptions of costs, altering the strength of the observed relationship. For example, older adults with negative views of aging may be more likely to exaggerate the costs of engagement than those with more positive views, resulting in differences in the strength of the observed relationship. As a working hypothesis, we predicted that workload assessments will predict SBP-R in both age groups. We further investigated the hypothesis that the expected age differences in responses to cognitive demands would also be reflected in subjective perceptions of workloads.

Method

Participants

The final sample included 100 participants: 50 older adults (25 women) 65 – 82 years of age ($M = 71.7$) and 50 younger adults (25 women) 18 – 38 years of age ($M = 29.3$), of which 82 were white, 16 African American, 1 Asian American, and 1 Native American. All participants were community-based volunteers from the lab's participant pool who were originally recruited through either newspaper and on-line advertisements, notices in community centers, or word of mouth. Demographic information is provided in Table 1. At recruitment, self-reported untreated high blood pressure (i.e., SBP > 160 mm Hg, or diastolic blood pressure [DBP] > 100 mm Hg) was used as an exclusionary criterion. In addition, five participants—not included in the above sample statistics—who came to the lab for testing, but whose blood pressure was over this criteria based on an initial lab screening, were dismissed from further participation. Each participant was paid $30.

Measures and Equipment

Cardiovascular (CV) responses—The Finometer MIDI (Finapres Medical Systems, Amsterdam, Netherlands) was used to collect continuous measures of blood pressure and heart rate (HR). The Finometer calculates these values through use of a finger cuff that measures finger arterial pressure. Through the BeatScope software provided in the system, finger arterial pressure was converted into predictions of Brachial artery blood pressure. The technology used in the Finometer MIDI has demonstrated reliability and validity (e.g. Gerin, Pieper, & Pickering, 1993; Podlesny & Kircher, 1999).

Memory search—The memory search task was similar to that used by Ennis et al. (2013). Using EPrime testing software, memory sets consisting 2, 4, or 6 randomly selected consonants were presented on a computer screen for 1000, 2500, and 4000 ms, respectively. (Increasing time of presentation with set size is common for this type of task [e.g., Anders & Fozard, 1973; Madden, Langley, Thurston, Whiting, & Blumenthal, 2003] and allows for an objective increase in the task demands while controlling for the additional time necessary for encoding stimuli as set size increased.) Following a 500 ms delay, a single target consonant was then presented. Participants indicated whether or not the target was contained in the memory set by pressing the appropriate button on the response box with their dominant hand.

Cognitive ability—For purposes of characterizing the sample, verbal ability, perceptual speed, and working memory were assessed using the vocabulary, digit-symbol-substitution, and letter-number-sequencing subtests from the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997).

Subjective ratings—Two sets of measures were included to assess participants' perceptions of the task. The first was NASA-TLX (Hart & Staveland, 1988), a well-validated measure of subjective workload. It uses information from six subscales assessing mental demand, physical demand, temporal demand, performance, effort, and frustration to create an overall measure of workload. An online version of the task (Sharek, 2011) was used in the present study.

Another instrument contained five items assessing general perceptions of the task relating to (a) perceived challenge (b) concerns that performance would reflect poorly on abilities, (c) nervousness induced by presence of the tester, (d) motivation to do well, and (e) importance of doing well. An additional item was included at posttest to assess perceptions of how worthwhile the task was. A 9-item scale was used for each rating.

Procedure

Prior to the laboratory session, participants completed background questionnaires sent to their homes. They were also assigned to either the high accountability (25 young, 24 old) or low accountability (25 young, 26 old) test conditions. Upon arriving at the laboratory, participants had their blood pressure screened using a HEM-780 automatic blood pressure monitor (Omron Healthcare, Inc., Kyoto, Japan). Next, a finger blood-pressure cuff was attached to the index, middle, or ring finger of the participant's non-dominant hand. CV baselines were established over a 5 min period, during which participants were free to read magazines provided by the lab. The memory search task was then explained to participants, and 5 practice trials were administered using memory sets of 3 items. Following practice, those in the high accountability condition were informed that the researchers would review their results with them at the end of each set of trials. In addition, actual feedback was provided after each trial. Participants in the low accountability condition were given standard instructions with no feedback about performance. All participants then completed the five-item task perception scale. Our manipulation of accountability is consistent with definitions and use in the literature, whereby "accountability refers to the implicit or explicit expectation that one may be called on to justify one's beliefs, feelings, and actions to others" (Lerner & Tetlock, 1999. p. 255), and performance evaluation is considered a major component of accountability (Ferris, Munyon, Basik, & Buckley, 2008).

The main memory search task was administered next. Participants completed 30 trials at each level of difficulty, with presentation order of the trial blocks associated with each difficulty level systematically varied across participants so that roughly equal numbers of participants within age groups and accountability conditions received items associated with each difficulty in each presentation position. CV responses were assessed continuously during testing, with markers made in the data record to note when each block of trials began and ended. At the end of each block, participants in the high accountability condition were shown how well they did, with the experimenter highlighting their performance. All participants then completed the NASA-TLX and another short series of questions assessing perceptions of difficulty, effort, and control associated with the trials at that difficulty level using a 9-point scale. The same procedure was followed for the remaining two trial blocks. After completion of the memory search task, the task perception scale was administered once again followed by the three ability tests. The participants were then paid and thanked for their participation.

Results

Participant Characteristics

Prior to our formal analyses, we conducted 2 × 2 (Age Group X Accountability) analyses of variance on background variables to determine any inadvertent biases in condition assignment. Importantly, there were no significant effects due to accountability. As can be seen in Table 1, the age differences on cognitive measures were in the expected direction, although the only significant age effect observed was for digit-symbol substitution. Significant differences between age groups in the expected directions were also obtained for self-reported mental and physical health. Finally, older adults had significantly more years of education than did younger adults.

Task Performance

We first examined performance on the memory search task. Accuracy (i.e., proportion of correct responses) was assessed using a 2 × 2 × 3 (Age Group X Accountability X Difficulty [memory sets of 2 vs. 4 vs. 6 items]) analysis of variance (ANOVA). The only significant effects obtained were associated with age group, $F(1,96) = 5.47$, $p = .02$, $\eta_p^2 = .05$, and difficulty, $F(2,192) = 96.20$, $p < .001$, $\eta_p^2 = .50$. Younger adults were more accurate than older adults (*M*s = .94 vs. .92) and accuracy was greater for memory set sizes of 2 and 4 than for 6 (*M*s = .97 & .96 vs. .87). An identical analysis on response times revealed similar effects, with younger adults (M = being faster than older adults (*M*s = 882ms vs. 1193 ms), $F(1,96) = 38.71$, $p < .001$, $\eta_p^2 = .29$, and response times increasing with memory set sizes (*M*s for 2, 4, and 6 items = 863ms, 1024ms, & 1224ms), $F(2,192) = 114.68$, $p < .001$, $\eta_p^2 = .54$. Thus, the effects observed on this task are similar to those observed elsewhere in the literature. Importantly, performance was relatively high in both age groups.

CV Responses

Our primary analyses focused on CV responses: For each participant, we calculated a baseline response for each CV index— SBP, DBP, and HR—based on the mean over the last 5 min of the baseline period, and then obtained change scores by subtracting baseline response from the mean response during each trial block of the memory search task. We then used multi-level modeling (MLM) to examine the impact of difficulty (i.e., memory set size) and presentation position (first, second, or third trial block)[2] (Level 1 variables), age group and accountability condition (Level 2 variables), and all within-level and cross-level interactions on mean scores within each trial block. Difficulty and presentation position varied across the three data points contributed to this analysis by each participant. Given that presentation position and difficulty were completely confounded across participants—thus not permitting use of traditional ANOVA-based analytic methods—MLM allowed us to examine the impact of each within the same analyses. MLM has several advantages over ANOVAs for analysis of this particular data set. First, it takes into account dependencies across observations, controlling for potential sources of covarition that might mask effects associated with our variables of interest. Second, MLM allows for estimation of the slope and intercept associated with difficulty and presentation and presentation position while controlling for the other. The young adults and low accountability condition were used as referents, and difficulty level and presentation position were indexed from 0 to 2. Using specific referents allows us to decompose interactions, and determine their direction and significance. In each analysis, the appropriate baseline CV response (mean-centered) was entered as a covariate to control for the possibility that magnitude of response was associated with baseline. We also controlled for performance (i.e., mean-centered accuracy).

The equations depicting these models are as follows:

$$\text{SBP-R}_{it} = \beta_{0it} + \beta_1\,(\text{Difficulty})_{it} + \beta_2(\text{PresentationPosition})_{it} + \beta_2\,(\text{Difficulty} \times \text{Presentation Position})_{it} + r_{it}$$
$$\beta_{0i} = \gamma_{00} + \gamma_{01}\,(\text{Accountability}) + \gamma_{02}\,(\text{Age}) + \gamma_{03}\,(\text{Accountability} \times \text{Age}) + \mu_{00i}\,(\text{Baseline SBP-R}) + \mu_{01i}$$
$$\beta_{1i} = \gamma_{10} + \gamma_{11}\,(\text{Accountability}) + \gamma_{12}\,(\text{Age}) + \gamma_{13}\,(\text{Accountability} \times \text{Age}) + \mu_{10i}\,(\text{Baseline SBP-R}) + \mu_{11i}$$

Fully unconditional null models were estimated for each of our three measures, and significant (all *p*s > .0004) within- and between-person variability was observed for each measure. For SBP-R, 82.4% of the variance was between- and 17.6% within-persons. For DBP response (DBP-R), 26.0 % was between- and 74% within-persons, and for HR response (HR-R), 70.7% was between- and 29.3% within-persons.

[2]Our initial models included quadratic effects relating to difficulty and trial block, but no significant effects were obtained. Thus, the reported analyses examine only the linear components.

The main focus was on our primary measure of interest: SBP-R. Results of this analysis are provided in Table 2. Consistent with expectations, SBP-R increased with age, accountability, task difficulty, and presentation position. Of greater interest were two significant 3-way cross-level interactions—Age X Accountability X Difficulty and Age X Accountability X Presentation Position—and the significant Age X Accountability X Difficulty X Position interaction. Given that younger adults were the referent—that is, effects in the model were estimated relative to this group—the results of this initial set of models indicate no moderation of the accountability, difficulty, and position effects in this group. Further analyses focused on the older group (i.e., changing the age group variable so that this group was now the referent) in order to tease apart the 4-way interaction revealed no significant effects associated with either difficulty or position in the low accountability condition (*p*s > .31). In contrast, SBP-R was positively associated with both difficulty, $b = 5.63$, $t(31) = 4.13$, p = .0003, and presentation position, $b = 3.42$, $t(94) = 2.64$, p = .01, in the high accountability condition, with the strength of both effects being greater than those observed for the young adults. The Difficulty X Position interaction was also significant, $b = -2.34$, $t(94) = -2.47$, p = .02. As can be seen in Figure 1, this effect was primarily due to the increase in effort associated with memory sets of size 2 as presentation position increased. Focused tests revealed that presentation position had a significant effect on responses associated with set sizes of 2 items, $b = 3.43$, $p = .01$, but not for set sizes of 4 or 6 (*p*s > .23).

We examined DBP-R using an identical analysis. The only significant effects obtained were the Age X Accountability X Difficulty interaction, $b = 10.27$, $t(62) = 2.36$, $p = .02$, and the Age X Accountability X Difficulty X Position interaction, $b = -5.54$, $t(62) = -2.11$, $p = .04$, with the form of these interactions being similar to those obtained with SBP-R. A final analysis examining HR-R revealed no significant effects. Thus, as expected, SBP-R was the CV measure that was most sensitive to factors relating to effort and engagement.

Workload Ratings

We next examined subjective workload using the previously described MLM analysis, substituting TLX scores as the dependent variable and excluding SBP baseline as a covariate. Full results of the MLM procedure are provided in Table 3. As expected, task difficulty was positively associated with TLX scores. The only other significant effect was the 4-way cross-level interaction (Figure 2). Once again, given that the young group was the reference group in this analysis, the absence of other effects not involving age suggest little systematic influence of any other variables on their ratings. As before, we then focused on the older group by re-running the models with this group as the referent. When this was done, there were no significant effects, but the Accountability X Difficulty X Presentation Position interaction approached significance, $b = -6.37$, $t(185) = -1.92$, $p = .06$. Somewhat counterintuitively, this reflected the fact that those in the low accountability condition had generally higher TLX scores than those in the high accountability condition, and also appeared to be more sensitive to task-related variables (i.e., difficulty, presentation position). This may suggest that those older adults who were not engaged in the task were more likely to view the task as effortful, with effort more likely to be stimulus-driven as opposed to reflecting more intrinsic processes. Notably, age differences were relatively small.

To examine the relationship between subjective perceptions of workload and effort, we substituted the grand-mean-centered TLX scores for task difficulty and position in the previously described models examining SBP-R. In doing so, we assumed that TLX scores would capture effort variability associated with these two variables. In our initial analyses, no significant effects were obtained due to TLX scores. These null effects were somewhat surprising, so we decided to conduct follow-up analyses using ratings from each of four of the individual scales—control, difficulty, effort, and try—comprising the TLX assessment. When this was done, the only significant effect involving any of these measures was an Age X Accountability X Effort interaction, $b = 1.35$, $t(194) = 2.00$, $p = .047$. When this effect was decomposed, it was found that effort ratings were positively associated with SBP-R, but only for the older adults in the high accountability condition, $b = 1.63$, $t(194) = 4.60$, $p < .0001$.

Perceptions of the Task and Test Situation

In a final set of analyses, we examined the ratings provided on the pre- and posttest questionnaires using a series of 2 × 2 × 2 (Age Group X Accountability X Time) ANOVAs. Two sets of ratings related to responses to the test session. Ratings reflecting concerns that performance would reflect poorly on them increased with time, $F(1,96) = 27.53$, $p < .001$, $\eta_p^2 = .22$, with accountability moderating this effect due to the increase being stronger in the high accountability condition (*M*s = 2.4 vs. 4.3) than in the low accountability condition (*M*s = 2.8 vs. 3.4), $F(1,96) = 6.54$, $p = .01$, $\eta_p^2 = .06$. This suggests that our accountability manipulation was effective. In addition, the absence of age moderating this interaction suggests that the obtained differential response across age groups in terms of effort was not based in differential perceptions of the task, but rather their response to the task.

We were also interested in examining responses to the testing situation that could reflect factors associated with anxiety (e.g., threat, frustration) since such responses could conceivably also result in increased arousal and potentially account for observed age differences in CV responses. When concerns about the tester's perception of them were examined, the only effect obtained was due to age, with younger adults exhibiting greater concerns than older adults (*M*s = 1.8 vs. 1.3), $F(1,96) = 5.25$, $p = .03$, $\eta_p^2 = .05$. We also examined raw ratings of frustration from the TLX scale, substituting difficulty level for the time factor since this assessment occurred for each level. The only significant effect obtained was for difficulty, $F(2,192) = 4.66$, $p = .01$, $\eta_p^2 = .05$, with mean scores for memory set sizes of 2, 4, and 6 being 18.1, 14.2, and 21. 1. Of note is that these scores were on a scale of 100, and thus frustration levels were relatively low for all participants, regardless of age. Thus, there was no evidence that older adults experienced heightened arousal responses to the test session relative to younger adults, reducing the possibility that the observed age differences in SBP-R were due to such factors.

Finally, participants also rated how challenging they thought the task would be/was. Perceptions of challenge increased from pre- to posttest, (*M*s = 3.1 vs. 6.0), $F(1,96) = 91.54$, $p < .001$, $\eta_p^2 = .49$., and older adults viewed the task as more challenging than did younger adults (*M*s = 5.0 vs. 4.2), $F(1,96) = 5.08$, $p = .02$, $\eta_p^2 = .06$. Interestingly, older adults also viewed the task as more worthwhile than did the younger adults, (*M*s = 7.0 vs. 5.7), $F(1,96)$

= 13.29, $p < .001$, $\eta_p^2 = .12$, although all participants' ratings were above the midpoint of the scale. One interpretation of the ratings of the task being worthwhile is that they reflect perceived task benefits. Thus, to control for the possibility that the observed age effects in engagement were not due to differences in perceived importance of the task, we re-ran our analyses of SBP-R while including worthwhile ratings as covariates. Its inclusion, however, did not impact the pattern of results. Two additional indices of motivation were examined next. For all participants, reported levels of motivation increased from pre- to posttest, (*M*s = 7.7 vs. 8.0), $F(1,96) = 5.43$, $p = .03$, $\eta_p^2 = .02$, as did ratings of importance assigned to doing well, (*M*s = 6.7 vs. 7.4), $F(1,96) = 14.18$, $p < .001$, $\eta_p^2 = .13$. No other effects were significant, including—somewhat curiously—those relating to accountability. In sum, these ratings suggested that young and older adults did not vary greatly in their perceptions of the task. This in turn reduces the number of alternative explanations for the obtained results.

Discussion

This study was designed to test some basic aspects of Selective Engagement Theory (Hess, 2014). Our primary goal was to determine whether older adults' resource engagement is disproportionally influenced by the personal implications of the task using a more direct measure of engagement than those used in previous tests of the theory. The results were consistent with expectations. Increasing accountability for their performance resulted in significant increases in SBP-R for both young and older adults, replicating previous research with younger adults demonstrating a positive association between motivation level and SBP-R (e.g., Gendolla, 1999; Silva, McCord, & Gendolla, 2010; Wright, Tunstall, Williams, Goodwin, & Harmon-Jones, 1995). More importantly, we observed that the accountability manipulation had a disproportionate effect on older adults' engagement of cognitive resources. This result is consistent with expectations drawn from the Selective Engagement framework, which argues that increases in the costs of cognitive engagement with age make older adults more sensitive to the personal implications of the task—in this case, self-presentation or ego involvement. Of particular importance is the fact that we demonstrated age-related selectivity using a measure of effort more directly reflective of resource mobilization. Most previous support for selective engagement relied on performance assessments (e.g., Hess et al., 2009; Zhang et al., 2013), which are imperfect reflections of engagement, whereas the use of SBP to assess effort expenditure permitted the assessment of engagement independent of performance.

A secondary goal was to replicate results relating to age differences in effort related to task demands found in the literature (Ennis et al., 2013; Hess & Ennis, 2012). As in these earlier studies, older adults exhibited higher levels of responsivity than younger adults at all levels of task difficulty. This result is suggestive of the increased costs of cognitive engagement in later life. Specifically, older adults must expend more effort than younger adults to achieve the same levels of objective task performance. We were also interested in assessing whether young and older adults modified their level of effort in a similar manner across levels of task difficulty. In previous research (Ennis et al., 2013; Hess & Ennis, 2012), there was some suggestion of a disproportionate increase in effort with increasing task difficulty in older adults. However, assessment of such effects in these studies was complicated either by the use of different tasks across levels of difficulty (Hess & Ennis) or by inclusion of high difficulty levels at which performance was compromised (Ennis et al.). Specifically, in the latter study, it appeared that some participants—particularly older adults—were disengaging from the task, as evidenced by decreases in SBP-R at the highest levels of difficulty. In the present study, we sought to avoid this by restricting the difficulty levels to those at which both younger and older adults would likely perform close to ceiling, indicating that the task was within their levels of skill, thereby decreasing the likelihood of disengagement. We achieved this goal as reflected in (a) the relatively high levels of performance across age groups and conditions and (b) the absence of quadratic effects in SBP-R across levels of difficulty.

Consistent with expectations, we found that both young and older adults demonstrated an increase in effort as task difficulty increased. Of interest is the fact that the impact of task difficulty varied across age groups as a function of accountability. For younger adults, the impact of difficulty on SBP-R was similar across levels of accountability. In contrast, SBP-R was only related to objective difficulty for those older adults in the high accountability condition. This may be a further reflection of selective engagement, as increased motivation not only influences level of effort expenditure, but also sensitivity of output to specific details of the task. This would include the ability to adaptively respond to the current demands of the task.

We also examined changes in SBP-R as a function of trial block as another way of examining responsivity to task demands. We have hypothesized that age-related cognitive costs can also be observed in the impact of prior sustained cognitive engagement on subsequent engagement, with the expectation that these costs will be reflected in elevated levels of effort in later trial blocks as older adults deal with the costs of engagement. Consistent with the findings for task difficulty, younger adults exhibited a small, but reliable increase in SBP-R across trial blocks that was not moderated by accountability. In contrast, a larger effect of trial block was observed for older adults, but the effect was only significant in the high accountability condition. This effect was further moderated by task difficulty, but the upshot was that motivated older adults appeared to invest more cognitive resources in performance as task difficulty—defined in terms of objective difficulty or sustained engagement over time—increased. This once more suggests that enhanced involvement in the task for older adults has a disproportionate impact on sensitivity and associated response to task demands.

The obtained results associated with SBP-R are consistent with expectations drawn from Wright’s (1996) integrative model, which incorporates aspects of Obrist’s (1981) active coping model and motivational intensity theory (e.g., Brehm & Self, 1989). Specifically, effort mobilization is associated with an increase in SBP due to myocardial beta-adrenergic activation, with the degree of effort expended dependent upon task demands and the extent to which the individual believes that the task is both worthwhile and within their capabilities. (Although there is some normative decline in beta-adrenergic activation in later life, this is compensated for by an increase in stroke volume to maintain cardiac output.) Thus, SBP-R is not simply a direct response to the difficulty of the task, but a complex measure of effort that reflects the characteristics of the participant. The observed effects relating to task difficulty and motivation in the present study are consistent with the model’s expectations.

The selective engagement framework (Hess, 2014) builds on these ideas by specifically addressing the effects of aging, which may influence engagement through its associations with task difficulty, perceived ability, and perceptions of task importance. The effects obtained in the present study can further be interpreted in terms of changes in engagement in later life due to increases in the costs of cognitive engagement, which influence task difficulty and willingness to engage, which would be related to both perceived willingness and benefits of engagement.

A potential alternative interpretation of the obtained age effects is that they reflect arousal and anxiety or frustration associated with the task, with older adults having stronger and more protracted physiological responses to such affective states (Charles, 2010). Whereas such an interpretation would not be inconsistent with selective engagement—to the extent that these heightened responses can be interpreted as costs—we argue that the age effects in the present study are more reflect of age differences in engagement for two primary reasons. First, the systematic response to task conditions observed for SBP-R would not necessarily be expected if anxiety was the operative mechanism. Second, there was little evidence of age differences in feelings of threat or frustration in our participants, with both young and older adults expressing relatively low levels of each.

A final goal of this study was to examine self-report measures (NASA-TLX) of workload and their relationship to SBP-R. Consistent with past use of this instrument, we found that workload scores were systematically related to task difficulty. There were, however, no age differences in workload ratings. This would not necessarily be unexpected given that participants were only rating the task relative to their own perspective as opposed to their experience relative to another's. Counterintuitively, older adults in the low accountability condition reported that the cognitive task involved a greater workload, and they also had greater sensitivity to task conditions than did older adults in the high accountability condition. This may reflect the generally lower levels of engagement by participants in this group, which in turn may have increased subjective awareness of task difficulty due to levels of effort exerted perhaps being less than optimal for supporting performance. An alternative, related explanation is based in theorizing by Kurzban, Duckworth, Kable, and Myers (2013), who hypothesized that the felt sensation of effort can be explained as being the result of a cost-benefit analysis. The greater the distance between the costs and benefits becomes, the more effort is felt by the participant. If accountability influenced perceived benefits, then it could be hypothesized that those in the low accountability—who presumably viewed the task has having relatively little personal benefit—perceived greater distance between costs and benefits, resulting in greater perceptions of effort.

Whereas TLX scores did increase with difficulty, surprisingly, there was little evidence of these scores predicting engagement. Our finding regarding the correspondence of aggregate difficulty and effort ratings with objective indices of difficulty and CV responses at the group level replicates much existing research with younger adults (e.g., Nolte, Wright, Turner, & Contrada, 2008; Wright et al., 2008), but most of these studies have not examined relationships between workload ratings and CV responses across and within individuals. Of those studies that have, such as research examining the influence of challenge appraisals on CV reactivity (e.g., Korunka, Zauchner, Litschauer, & Hinton, 1997; Tomaka, Blascovich, Kelsey, & Leitten, 1993), the results have been mixed. Ennis et al. (2013) observed that subjective ratings of task difficulty predicted SBP-R using a memory search task similar to that in the present study. Although somewhat different subjective indices were used in the Ennis et al. study, the reasons for the discrepancy with the present results are unclear other than the possibility the greater number of difficulty levels included in that study captured more variance in engagement. It may be the case that, although linked to energy expenditure and active coping, changes in SBP-R may be difficult to detect and quantify at a conscious level, accounting for the inconsistency in results. It may be that more indirect assessments of task perceptions that build on experience may be better predictors. For example, Westbrook, Kester, and Braver (2013) indirectly assessed subjective perceptions of cognitive load using a discounting task wherein they determined the monetary reward necessary to induce an individual to perform a more difficult as opposed to less difficult task (e.g., *N*-back tasks involving *N* of 2 vs. 1). They observed subjective value scores derived from the discounting task did a much better job of accounting for difficulty and age effects in performance than did TLX workload scores.

In conclusion, the results of this study add additional support for basic tenets of Selective Engagement Theory. First, we have demonstrated that age is associated with increased costs associated with cognitive engagement in terms of (a) the effort required to perform a task at a specific fixed level of objective task difficulty and (b) depletion effects. These costs were reflected in the greater impact of task difficulty (i.e., size of the memory set) and task duration (i.e., change over trial blocks) on older relative to younger condition under conditions associated with high involvement in the task (i.e., the high accountability condition). Second, we demonstrated that engagement—assessed independently of task performance—was disproportionately associated with the personal implications of the task in the older relative to the younger adults. This is consistent with the hypothesis that the increased costs of engagement will result in greater selectivity in engagement of cognitive resources in later life. Finally, we did not observe a strong relationship between subjective measures of workload and task engagement. This suggests that conscious assessments of task involvement may not easily map onto physiological measures associated with energy expenditure at the individual level. To the extent that increased costs influence involvement in cognitively demanding everyday tasks, this leaves open the question as to how costs influence behavior.

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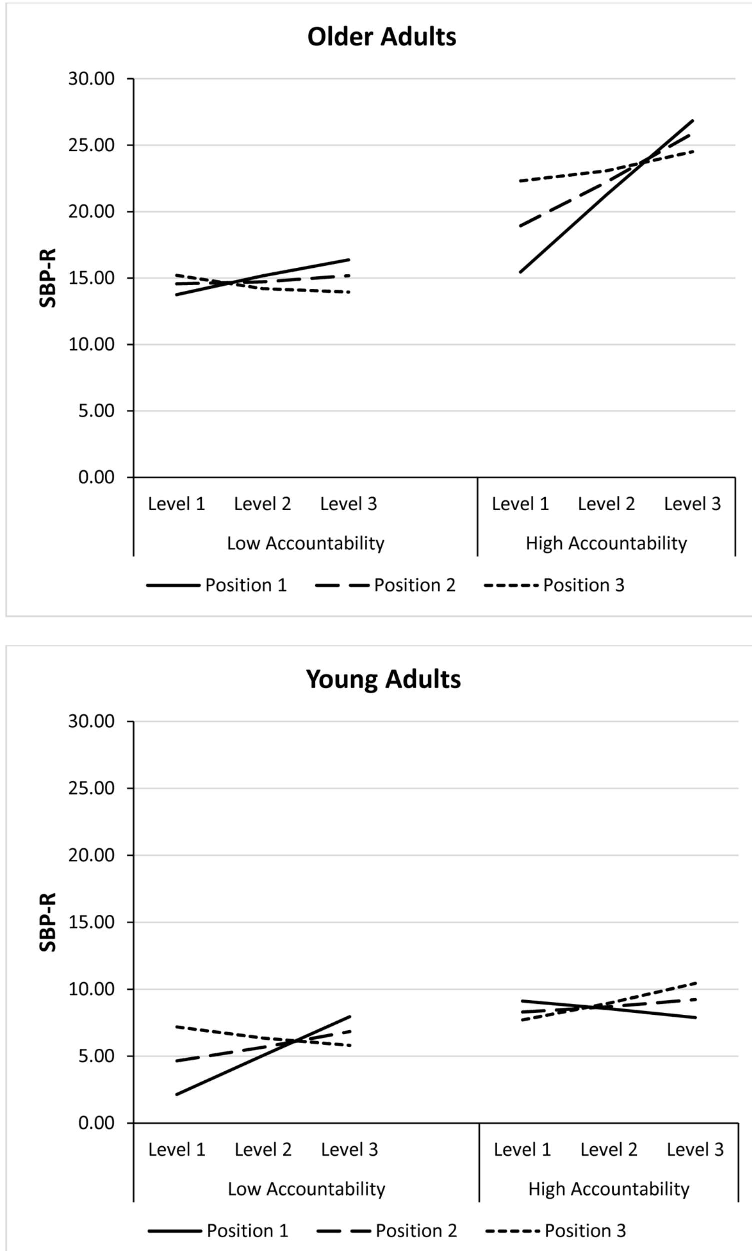

Figure 1.

SBP-R estimates as a function of age, accountability, difficulty level, and presentation position.

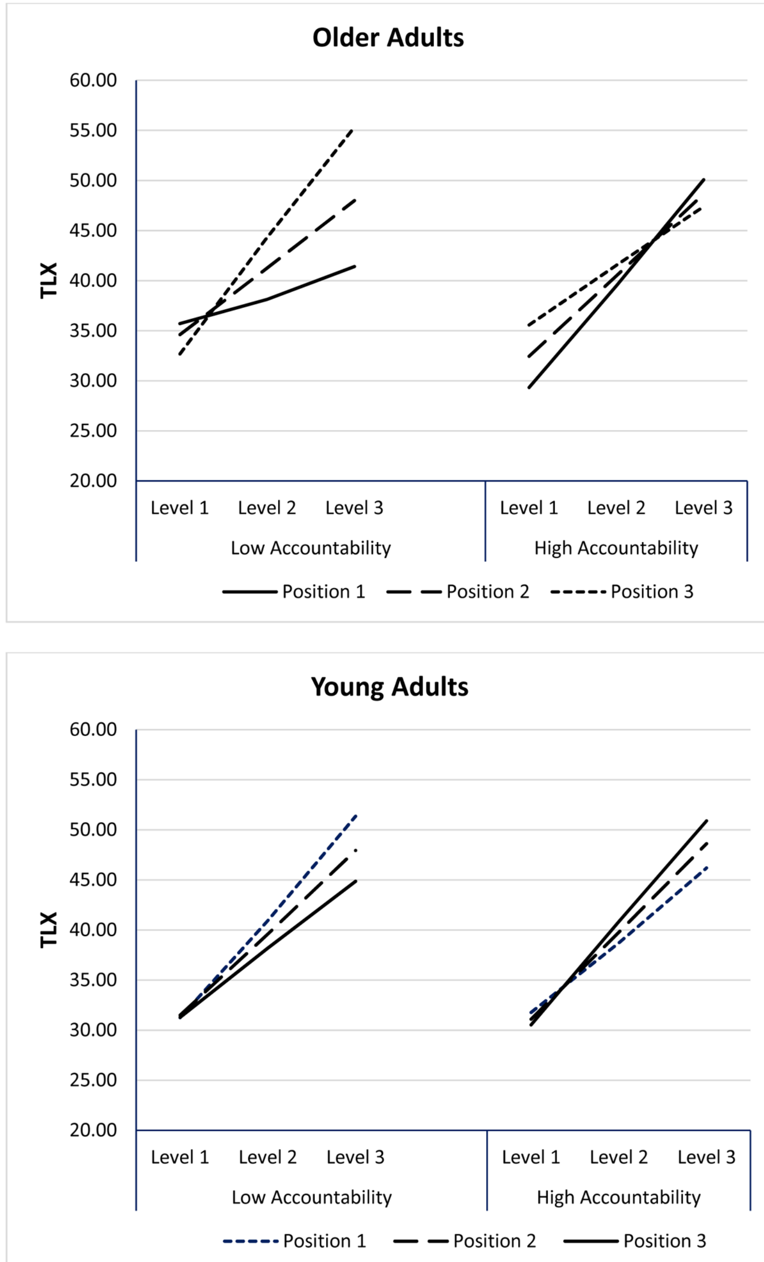

Figure 2.
TLX ratings as function of age, accountability, task difficulty, and trial block.

Table 1

Demographic Data

	Young Adults		Older Adults	
	M	***SD***	***M***	***SD***
Age (years)	29.3	6.2	71.7	5.0
Education (years) *	15.6	2.2	17.3	2.1
SF36 Physical Health *	50.8	6.8	45.3	7.8
SF36 Mental Health *	50.3	8.1	57.3	6.7
Baseline HR (bpm)	75.0	10.2	72.0	10.6
Baseline SBP (mmHg) *	114.8	12.9	127.8	19.3
Baseline DBP (mmHg) *	68.7	8.9	64.5	9.9
WAIS III Vocabulary	48.7	9.0	51.42	9.0
WAIS III Digit-Symbol Substitution *	83.7	18.4	70.10	15.2
WAIS III Letter-Number Sequencing	12.3	2.7	11.4	2.6

*Age difference significant at $p < .05$.

Table 2

Results of the Multilevel Model for Systolic Blood Pressure Responsivity

Effect	Estimate	Standard Error	*p-Value*
Intercept	2.13	2.20	.334
Age	11.62	3.04	<.001
Accountability	6.97	3.04	.025
Presentation Position	2.53	1.27	.049
Difficulty	2.83	1.13	.040
SBP Baseline	−.170	.052	.002
Age x Presentation Pos.	−1.80	1.78	.326
Age x Accountability	−5.25	4.27	.224
Age x Difficulty	−1.79	1.84	.364
Accountability x Pres. Pos.	−3.22	1.79	.077
Presentation Pos. x Difficulty	−1.79	.930	.058
Accountability x Difficulty	−3.25	1.85	.083
Age x Accountability x Pres. Pos.	5.92	2.55	.023
Age x Pres. Pos x Difficulty	0.867	1.31	.509
Age x Accountability x Difficulty	7.74	2.62	.004
Accountability x Pres. Pos. x Difficulty	2.55	1.31	.056
Age x Accountability x Pres Pos. x Difficulty	−3.97	1.86	.037

Table 3

Results of the Multilevel Model for the NASA-TLX

Effect	Estimate	Standard Error	*p*-Value
Intercept	28.0	4.98	<.001
Age	5.34	6.90	.441
Accountability	2.63	7.04	.709
Presentation Position	.029	3.25	.927
Difficulty	12.00	3.33	<.001
Age x Presentation Pos.	−1.59	4.62	.731
Age x Accountability	−9.60	9.89	.334
Age x Difficulty	−6.90	4.65	.139
Accountability x Pres. Pos.	−1.99	4.59	.665
Presentation Pos. x Difficulty	−1.41	2.48	.571
Accountability x Difficulty	−3.80	4.67	.417
Age x Accountability x Pres. Pos.	6.90	6.55	.294
Age x Pres. Pos x Difficulty	5.95	3.50	.091
Age x Accountability x Difficulty	11.88	6.59	.073
Accountability x Pres. Pos. x Difficulty	3.74	3.49	.286
Age x Accountability x Pres Pos. x Difficulty	−10.44	4.96	.037