Attention, Workload, and Performance:

A Dual-Task Simulated Shooting Study

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Abstract

During skill execution, performers have been shown to attend to different aspects of movement, the external effects of one's action, or to other environmental information. A variety of psychological mechanisms have been proposed to account for the differential outcomes when adopting each attentional strategy. However, there is limited information about the extent to which different attentional foci change the workload demands of task performance. To examine this, the current study administered the NASA-Task Load Index following a simulated shooting dual-task. Participants performed the primary shooting task alone (control), and also with a secondary task that directed attention toward an aspect of skill execution (skill-focused) and an unrelated environmental stimulus (extraneous focus). Primary and secondary task performances were significantly greater in the extraneous focus compared to the skill-focused dual-task. Also, workload was significantly lower during the extraneous focus compared to the skill-focused dual-task condition. Further analyses revealed that workload significantly mediated the effects of skill level on performance during the skill-focused and extraneous focus dual-tasks and various subscales of workload (i.e., temporal demand) contributed unique amounts of variance to this relationship. A discussion of the relationship between attention, workload and its subcomponents, skill level, and performance is presented.

Keywords: Extraneous Focus of Attention, Skill-Focused Attention, Handgun Shooting, Bootstrapping, NASA-Task Load Index.

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The attentional mechanisms used during online skill execution have received considerable attention (e.g., Beilock, Carr, MacMahon, & Starkes, 2002). Lower-skilled performers are thought to attend to the step-by-step components of skill execution (see Anderson, 1982; 1983); whereas, high-skilled performance is believed to be automated and regulated at upper levels of cognition (Vallacher, 1993; Vallacher & Wegner, 1987). Redirecting higher-skilled performers' attention, however, to lower-order control processes can result in a disruption of proceduralized knowledge (Baumesiter, 1984; Langer & Imber, 1979; Lewis & Linder, 1997), but may benefit those who are still in the early phases of learning (compared to an extraneous distractor task - see Beilock & Carr, 2001). The skill level on performance questions are typically investigated using a dual-task methodology. Some of this research explains performance differences through kinematic analyses (e.g., Gray, 2004) or uses the methodology as a way to explore the likelihood of performance degradation as a function of skill (Beilock & Carr, 2001). Less research, however, has examined subjective perceptions of task demands (i.e., workload) and how this may influence performance across skill levels. In this experiment, we explored whether the effects of skill level on dual-task performance are a function of the workload demands posed by secondary tasks designed to manipulate attentional focus.

Dual-Tasks and workload

A number of researchers have used a dual-task methodology to manipulate attentional focus (Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock & Gray, 2012; Gray, 2004). To do this, researchers have used a distracting and extraneous secondary task, such as auditory tone counting, to direct participants' attention externally and away from skill execution itself. Likewise, to direct attention towards skill execution, participants are asked to explicitly name a particular part of the action being performed (e.g., direction of bat swing in a baseball batting task; side of foot contacting the ball in a soccer dribbling task, etc.) in addition to performing the primary task. Following traditional theories of skill acquisition (e.g., Anderson, 1982; Fitts & Posner, 1967), those adopting these dual-task methods have suggested that when individuals are in the early phases of learning (i.e., novices) they typically devote most, if not all, of their attentional resources to the control structures of movement during skill execution. In contrast, more experienced individuals need to devote few, if any, attentional resources to motor skill execution, especially to lower-order aspects of movement coordination and control, as skill execution is controlled by automatic processes.

Based on these assumptions, researchers have made different predictions for experts and novices engaging in secondary tasks that direct attention internally (i.e., toward skill execution) and externally (i.e., toward an extraneous task). When engaging in a distracting secondary task in addition to their primary task, novice performance is expected to be impaired—due to insufficient resource availability—whereas expert performance is not (see Beilock, Wierenga, & Carr, 2002). On the other hand, using a secondary task to direct attention toward a novice's movement—to which they are expected to be attending already since skill execution is expected to be cognitively mediated in a step-by-step manner—is not expected to be disruptive to their performance (Anderson, 1983, 1993; Fitts & Posner, 1967; Proctor & Dutta, 1995). However, when the attention of experts is directed towards skill execution via a secondary task (i.e., skill-focused attention; see Castaneda and Gray, 2007; Gray, 2004), based on Masters' re-investment hypothesis (1992), de-automatization of the previously habituated skill is expected, resulting in performance breakdown or 'choking' (Baumeister, 1984; Lewis & Linder, 1997; Masters, 1992). In general, these studies have demonstrated that an extraneous focus of attention is superior to skill-focused attention for both the performance and learning of experts (Castaneda &Gray, 2007; Gray, 2004); whereas, skill-focused attention has shown to be superior to an extraneous focus of attention for novices (Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock & Gray, 2012). Researchers using a dual-task methodology (Beilock & Carr, 2001; Beilock, Bertenthal, McCoy, & Carr, 2004; Gray, 2004) can then assess adherence to a secondary task, and the accuracy with which it is performed, by examining secondary task performance. Moreover, the purpose of the dual-task method is not only to direct attentional focus, but to assess the cognitive resource demand attributable to tasks (e.g., Abernethy, 1988).

In addition to assessing dual-task performance as a way to understand task demand, it would be useful to integrate a subjective measure as a way to quantify the perceived workload exhibited from dual-tasks that could then be compared across skill level. This would provide us with additional information on the cognitive component driving the skill level on dual-task performance relationship. The National Aeronautics and Space Administration-Task Load Index (NASA-TLX; Hart & Staveland, 1988) was incorporated into the current study. The NASA-TLX is a validated psychometric tool widely used in the human factors and human performance communities to measure different subjective dimensions of task-related workload. For example, the NASA-TLX has been used to examine measures of performance and its association with physiological responses (e.g., Prinzel, Pope, & Freeman, 2001), or the unanticipated workload increase exhibited from vigilance tasks that induce boredom (e.g., Warm, Dember, & Hancock, 1996). The NASA-TLX analyzes demands through subjective ratings of the task’s physical, mental, and temporal components. Furthermore, it allows for a self-assessment of performance efficiency (i.e., through perceptions of on-task effort investment), performance effectiveness, and an assessment of the subjective feelings of stress and frustration associated with increased workload. The NASA TLX has been used extensively in human performance research utilizing dual-task methodology (e.g., DiDomenico & Nussbaum, 2008; Haga, Shinoda, & Kokubun, 2002; Peter, Silvia, Yolanda, & Klaus, 2009; Recarte, Perez, Conchillo, & Nunes, 2008) and has wide applicability across domains (see Stanton, Salmon, Walker, Baber, & Jenkins, 2005).

Purpose, rationale, and hypotheses

The purpose of this study was to determine whether the effects of skill level on extraneous and skill-focused dual-task performance occurs through perceptions of workload. Previous literature using a secondary task to manipulate attentional focus indicates that the performance of skilled participants would be degraded by skill-focused attention, whereas that of lower-skilled participants would be facilitated (Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Wierenga, & Carr, 2002; Castaneda & Gray 2007; Gray, 2004). Accordingly, the following hypotheses were made: Outcome measures of the primary shooting task performance for higher-skilled participants were expected to degrade under skill-focused conditions and, therefore, workload was expected to be higher, compared with the extraneous focus dual-task condition. Shooting performance, however, for lower-skilled participants, was expected to be better and, therefore, workload was expected to be lower during the skill-focused compared to the extraneous focus dual-task. Given our expectations about the workload effects associated with each dual-task, we examined the mediating effects of workload on the relationship between skill level on performance on the primary task under both extraneous and skill-focused dual-task conditions. Specifically, we hypothesized that the indirect effect of participants' subjective ratings of workload would explain a substantial portion of the variance in the relationship between skill level and primary task performance for both attentional focus conditions. We also examined specific subcomponents of workload (e.g., mental demand, temporal demand) across skill level and via mediation analyses; however, since workload is a new construct within the dual-task literature, these analyses were exploratory with no specific predictions made *a priori*.

Methods

Participants

Thirty-six healthy participants (n = 17 males; n = 19 females) volunteered to take part in the study. Participants were naïve to the purpose of the study, and did not have any formal weapons training (e.g., law enforcement training). Participants were subsequently classified into higher and lower-skilled groups based on single-task performance (see below). The institutional ethics committee approved the project and informed consent was obtained prior to commencing the study.

Apparatus and task

Shooting Materials

Participants were equipped with a belt, gun holster, and modified Glock 17 handgun. The handgun was modified to emit an infrared laser and was used to fire at a projector screen which depicted a simulated firing lane with two targets (see Figure 1). Each target resembled a dart board with a bull's-eye surrounded by four concentric circles. The diameter of the bull's-eye was 2.5 cm and each surrounding circle increased its diameter by another 2.5 cm. The shooting system was calibrated before each participant to maintain accuracy amongst the projected image, infrared camera, and handgun. Participants stood 4.57 meters away from the projector screen for all shooting tasks, and were video-recorded to assess the level of adherence to the secondary task. Since Gray (2004) only found significant differences in secondary task accuracy (not response time), we measured accuracy using video-playback. Six participants were excluded from these video analyses due to video-recording malfunctions. These six participants were kept in the performance and workload analyses since this data was unaffected.

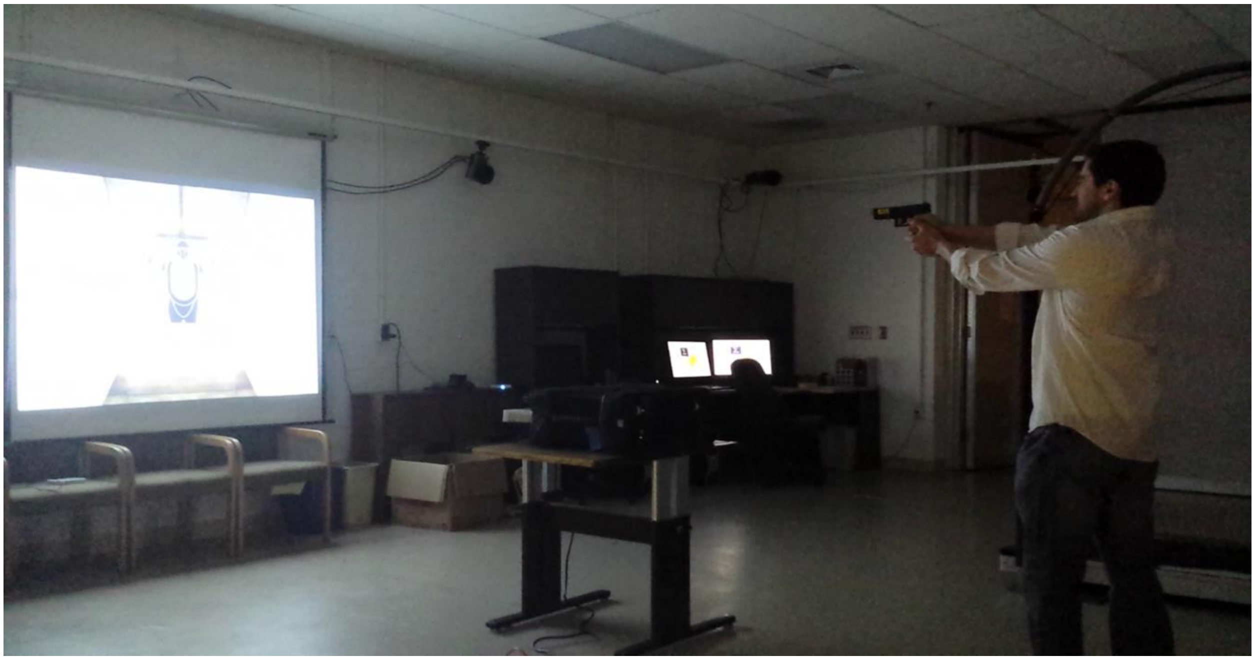

Figure 1. Picture of a participant completing the virtual target shooting task. Participants stood 4.57 meters away from a projector screen and fired a modified Glock 17 handgun equipped with an infrared laser.

Protocol

A variation of previously used dual-task methodology for attentional focus (Beilock & Gray, 2012; Castaneda & Gray 2007, Gray, 2004) was used for the present study and modified for handgun shooting following Suss and Ward (2010). Specifically, participants were required to complete a draw-shoot-holster task. Participants were instructed to draw the gun from the holster, fire two shots at each of two separate targets, and re-holster the weapon. All participants completed the draw-shoot-holster task with no stress elicited (single-task, control condition), an internal focus condition directed at skill execution (skill-focused dual-task), and an external focus condition directed towards an extraneous distractor (extraneous focus dual-task). Each task was repeated 10 times per condition (40 shots per condition; 120 shots total). In the skill-focused condition, participants were instructed to report the position of their trigger finger on hearing an audible stimulus while completing the primary draw-shoot-holster task. Specifically, participants had to verbally report if their trigger finger was either squeezing the trigger (in), releasing the trigger (out), or completely off the trigger (off) after a randomly-timed auditory tone (of any frequency) had been played (see Suss & Ward, 2010). In the extraneous focus condition, participants were required to identify whether the randomly-timed audible tone was low (493.88 Hz), medium (987.77 Hz), or high (1975.53 Hz) in frequency while completing the primary task. For both the skill-focused and extraneous focus conditions, participants were told to “respond as quickly and accurately as possible.” Participants in the control condition were required to complete the primary task only. The order of attentional focus conditions were counterbalanced between participants.

Dependent variables

Shooting Performance

A scoring system was adapted from previous work on attentional focus and dart throwing (Marchant, Clough, & Crawshaw, 2007; Marchant, Clough, Crawshaw, & Levy, 2009; McKay & Wulf, 2012; Radlo, Steinberg, Singer, Barba, Melnikov, 2002). Any shot that landed within the ‘bull’s-eye’ was worth 5 points and each surrounding circle depreciated in value by 1 point. The total value of all shots fired during each condition was summed to determine an overall ‘shooting performance’ score.

Workload

To measure workload associated with the different shooting tasks and attentional focus conditions, the NASA-TLX was administered upon completion of each condition. The NASA TLX requires participants to rate on six separate visual analogue sub-scales their perceptions of the physical, mental and temporal demands of the task, the effort invested and frustration experienced. These scales ranged from very low (scored as ‘0’) to very high (scored as ‘20’). The last of the six subscales requires participants to rate their own performance on a similar analogue scale (from perfect to failure). Thus, the six subscales consisting of mental demand, physical demand, temporal demand, performance, effort, and frustration were analyzed within this manuscript. Additionally, the total score on all six items were summed and divided by the number of subscales, resulting in a score out of 20, representing the highest level of workload.

Data analyses

A median split was used to separate participants into two skill groups based on their single-task (control) score. The top half (n = 18) were categorized as higher-skilled and the bottom half (n = 18), as lower-skilled (see Wright & Erdal, 2008). An independent t-test revealed that the higher-skilled participants (M = 157.39, SD = 14.36) scored significantly higher during the control condition than the lower-skilled participants (M = 104.28, SD = 31.84), t (34) = 6.45, p < .001. Then, to verify that our dual-task was effective in eliciting poorer primary task performance, we collapsed the dual-task performance scores into single variable and compared it with the control score using a paired-samples t-test. Next, we conducted nine separate mixed ANOVAs with skill level as the between-subjects factor and the attention condition (skill-focused, extraneous focus) as the within-subjects variable for the dependent variables of shooting performance, workload, mental demand, physical demand, temporal demand, performance, effort, frustration, and secondary task performance. Then, to determine the relationship between skill level, workload and its subcomponents, and performance, separate mediation analyses were conducted for each dual-task condition. A bootstrapping procedure that creates bias-corrected confidence intervals was used following Preacher and Hayes (2008) to assess the indirect effects of skill level on performance through workload and each of its subcomponents – significant mediation was present if the confidence intervals did not include zero.

Results

Single-task versus dual-task shooting performance

Participants performed significantly better during the single-task (M = 130.83, SD = 36.30) than the dual-tasks (M = 121.07, SD = 35.20), t (35) = 3.38, p = .002, indicating that our dual-task manipulation was effective in reducing primary task performance (see Figure 2).

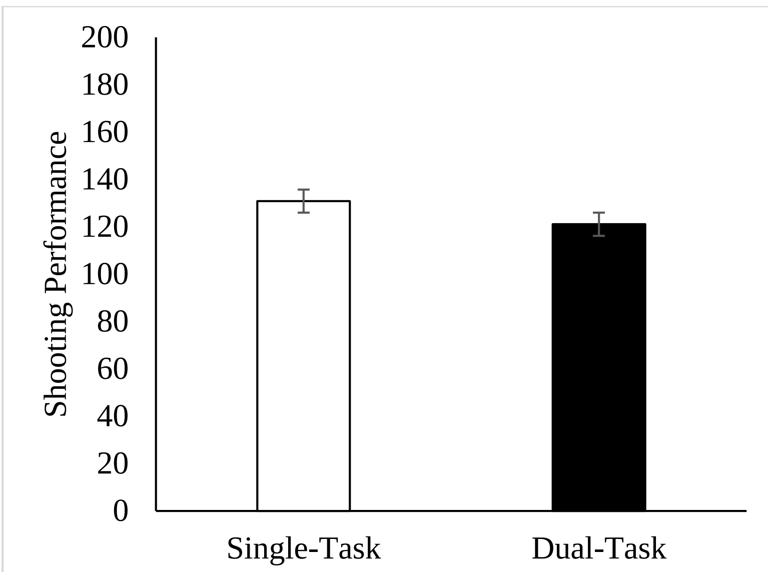

Figure 2: Mean shooting performance scores during the single task compared to the dual-tasks. Participants performed significantly higher during the single task compared to the dual-task (p = .002). Error bars indicate +/- 1 standard error of the mean.

Shooting Performance

There was a main effect for skill level; higher-skilled participants (M = 147.61, SD = 20.79) performed significantly better than lower-skilled participants under dual-task conditions (M = 94.53, SD = 32.22), F(1, 34) = 47.87, p < .001, partial η^2 = .59. There was also a main effect for attention condition; participants performed significantly better in the extraneous focus

(M = 127.36, SD = 36.20) than the skill-focused dual-task condition (M = 114.78, SD = 39.09), $F(1, 34) = 7.73$, $p = .009$, partial $\eta^2 = .19$. The Skill level × Attention interaction was non-significant ($p > .05$; see Figure 3).

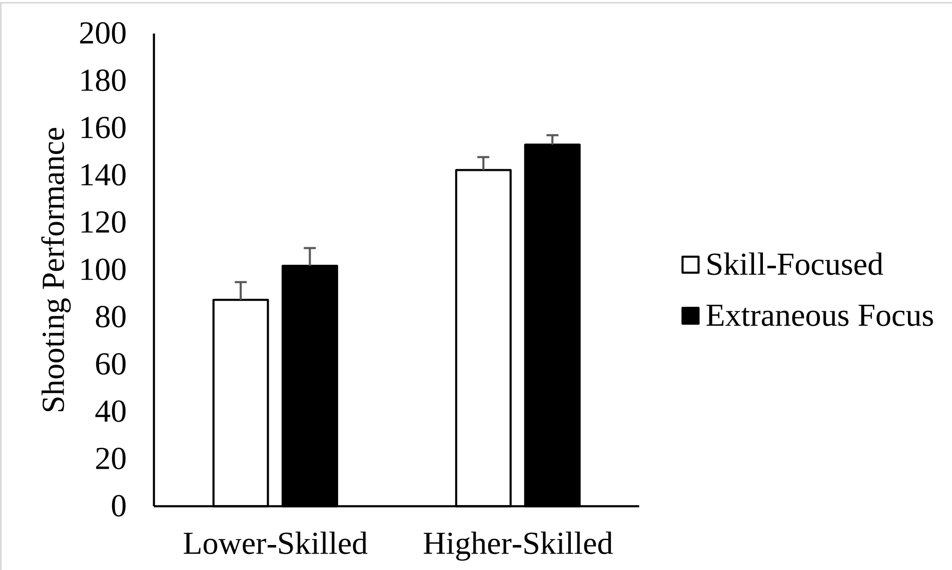

Figure 3: Mean shooting performance scores for each condition. Main effect for skill level, the higher-skilled participants' shooting performance was significantly higher than the lower-skilled participants ($p < .01$). Main effect for attention condition, participants' shooting performance was significantly higher during the extraneous focus than the skill-focused condition ($p = .009$). Error bars indicate +/- 1 standard error of the mean.

Workload

A main effect for skill level was present. The lower-skilled participants (M = 12.77, SD = 3.17) reported significantly higher levels of workload compared to the higher-skilled participants (M = 9.93, SD = 3.39), $F(1, 34) = 8.05$, $p = .008$, partial $\eta^2 = .19$. There was also a significant main effect for attention condition. Workload was significantly higher during the skill-focused (M = 12.09, SD = 3.66) than the extraneous focus condition (M = 10.61, SD = 3.34), $F(1, 34) = 13.57$, $p = .001$, partial $\eta^2 = .29$. The Skill level × Attention interaction was non-significant ($p > .05$; see Figure 4).

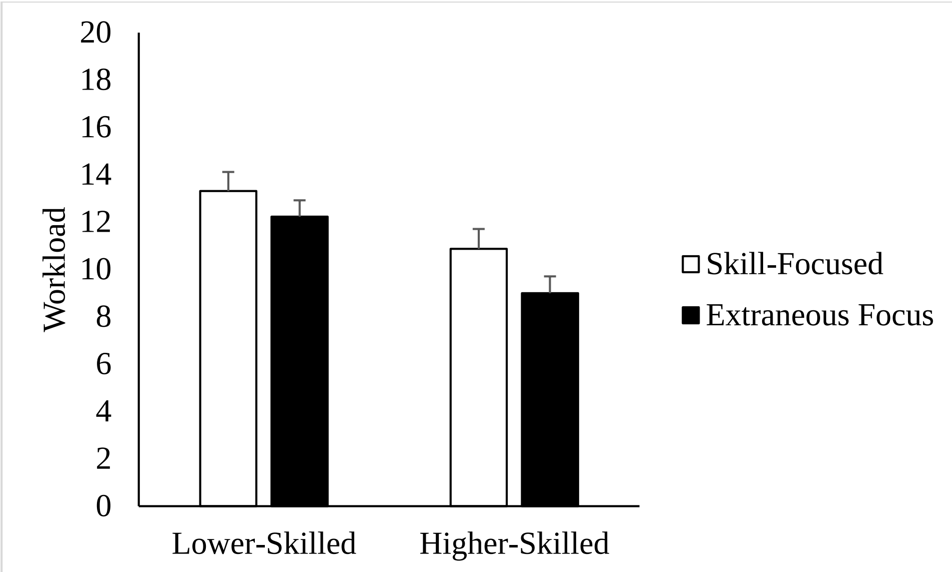

Figure 4. Mean perceived workload for each condition. Main effect for attention condition, participants reported significantly higher workload during the skill-focused than the extraneous focus condition (p = .001). Error bars indicate +/- 1 standard error of the mean.

Mental Demand

A main effect for skill level was present. The lower-skilled participants (M = 15.22, SD = 3.83) reported significantly higher levels of mental demand compared to the higher-skilled participants (M = 12.01, SD = 4.57), $F(1, 34) = 6.36$, $p = .02$, partial $\eta^2 = .16$. There was also a significant main effect for attention condition. Mental demand was significantly higher during the skill-focused (M = 14.39, SD = 4.64) than the extraneous focus condition (M = 12.84, SD = 4.26), $F(1, 34) = 7.56$, $p = .009$, partial $\eta^2 = .18$. The Skill level × Attention interaction was non-significant ($p > .05$; see Figure 5).

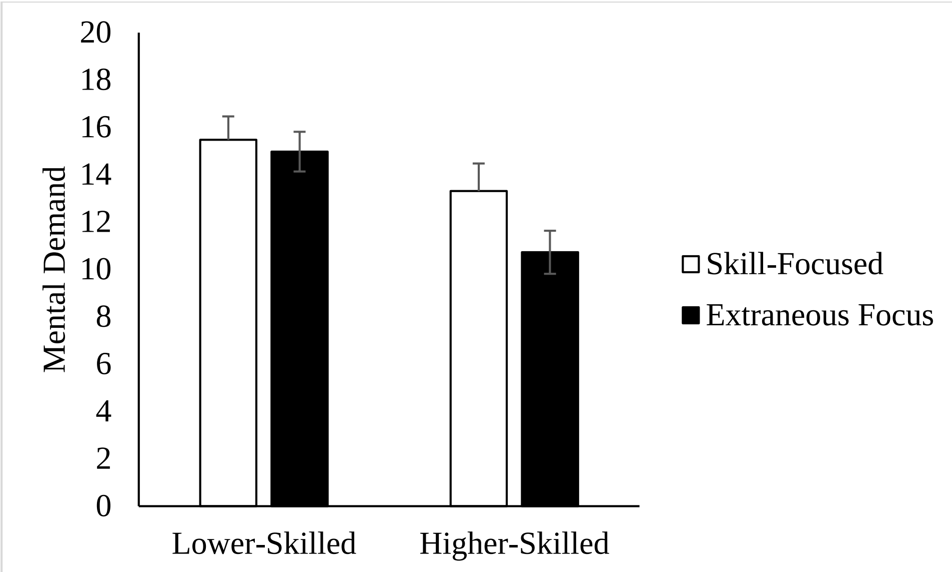

Figure 5. Mean perceived mental demand for each condition. Main effect for skill level, the lower-skilled participants reported significantly higher mental demand compared to the higher-skilled participants (p = .02). Main effect for condition, participants reported significantly higher mental demand during the skill-focused condition than the extraneous focus condition (p = .009). Error bars indicate +/- 1 standard error of the mean.

Physical Demand

There was no significant skill, attention condition, or Skill level × Attention interaction (all ps > .05).

Temporal Demand

A main effect for skill level was present. The lower-skilled participants (M = 15.11, SD = 3.83) reported significantly higher levels of temporal demand compared to the higher-skilled participants (M = 11.68, SD = 3.92), $F(1, 34) = 9.08$, $p = .005$, partial $\eta^2 = .21$. There was also a significant main effect for attention condition. Temporal demand was significantly higher during the skill-focused (M = 14.43, SD = 4.31) than the extraneous focus condition (M = 12.36, SD = 3.32), $F(1, 34) = 14.54$, $p = .001$, partial $\eta^2 = .30$. The Skill level × Attention interaction was non-significant ($p > .05$; see Figure 6).

Figure 6. Mean perceived temporal demand for each condition. Main effect for skill level, the lower-skilled participants reported significantly higher temporal demand compared to the higher-skilled participants (p = .005). Main effect for condition, participants reported significantly higher temporal demand during the skill-focused condition than the extraneous focus condition (p = .001). Error bars indicate +/- 1 standard error of the mean.

Performance

A main effect for attention condition was present. Participants rated their performance poorer during the skill-focused (M = 12.71, SD = 3.61) than the extraneous focus condition (M = 9.94, SD = 2.72), $F(1, 34) = 16.36$, $p < .001$, partial $\eta^2 = .33$. The skill level main effect and Skill level × Attention interaction were non-significant (all ps > .05; see Figure 7).

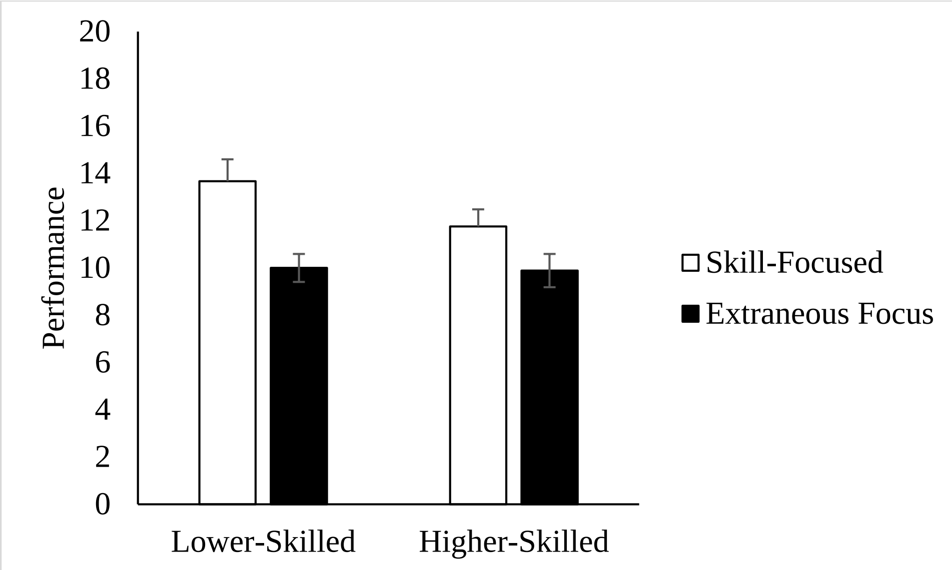

Figure 7. Mean perceived performance for each condition. Main effect for condition, participants reported significantly higher performance during the skill-focused condition than the extraneous focus condition ($p < .001$). Error bars indicate +/- 1 standard error of the mean.

Effort

A main effect for skill level was present. The lower-skilled participants ($M = 14.28$, $SD = 4.45$) reported significantly higher levels of effort compared to the higher-skilled participants ($M = 11.56$, $SD = 4.19$), $F(1, 34) = 3.98$, $p = .05$, partial $\eta^2 = .11$. There was also a significant main effect for attention condition. Effort was significantly higher during the skill-focused ($M = 13.72$, $SD = 4.39$) than the extraneous focus condition ($M = 12.11$, $SD = 4.54$), $F(1, 34) = 14.39$, $p = .001$, partial $\eta^2 = .30$. The Skill level × Attention interaction was non-significant ($p > .05$; see Figure 8).

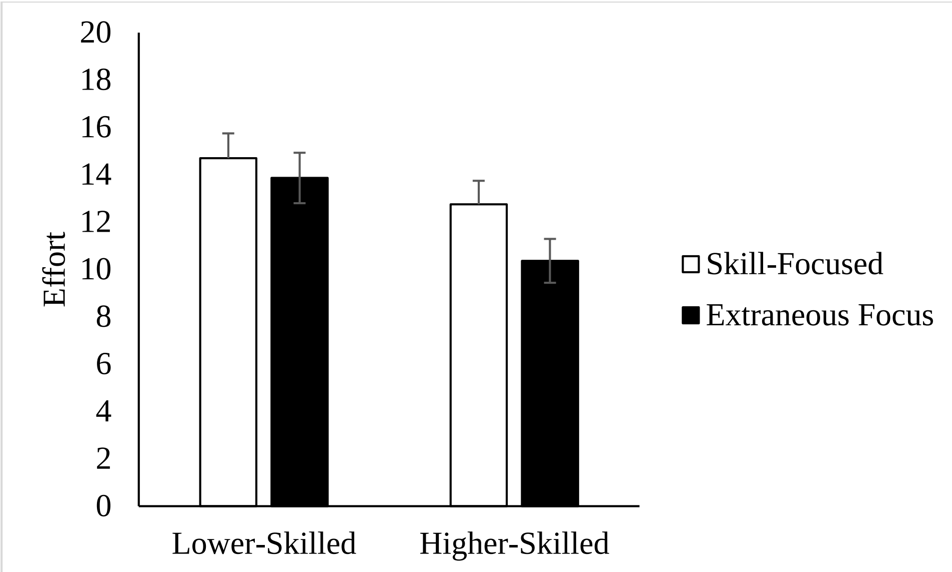

Figure 8. Mean perceived effort for each condition. Main effect for skill level, the lower-skilled participants reported significantly higher effort compared to the higher-skilled participants (p = .05). Main effect for condition, participants reported significantly higher temporal demand during the skill-focused condition than the extraneous focus condition (p = .001). Error bars indicate +/- 1 standard error of the mean.

Frustration

A main effect for skill level was present. The lower-skilled participants (M = 11.15, SD = 5.21) reported significantly higher frustration compared to the higher-skilled participants (M = 7.25, SD = 4.30), $F(1, 34) = 7.52$, p = .01, partial η^2 = .18. The attention main effect and Skill level × Attention interaction were non-significant (all ps > .05; see Figure 9).

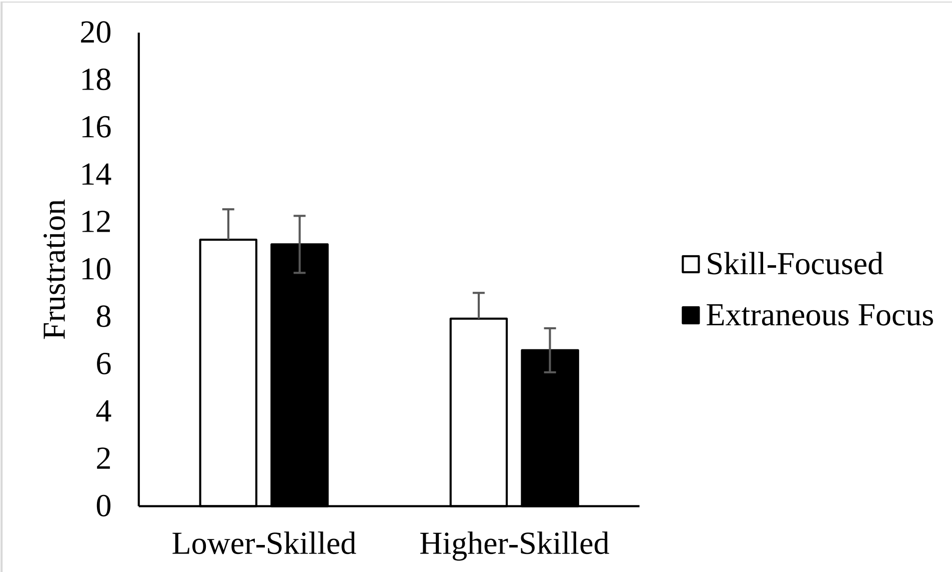

Figure 9. Mean perceived frustration for each condition. Main effect for skill level, lower-skilled participants reported significantly higher frustration compared to the higher-skilled participants (p = .01). Error bars indicate +/- 1 standard error of the mean.

Secondary Task Performance

There was a significant main effect for attention condition. Participants in the skill-focused condition (M = 5.85, SD = 4.51) had significantly more errors than those in the extraneous focus condition (M = 3.40, SD = 3.22), $F(1, 28) = 6.49$, p = .017, partial η^2 = .19. There was no significant main effect for skill level or Skill level × Attention interaction (all ps > .05; see Figure 10).

Figure 10. Mean number of errors on the secondary task for each condition. Main effect for condition. Significantly more errors occurred during the skill-focused than extraneous focus condition (p = .017). Error bars indicate +/- 1 standard error of the mean.

Mediation Analyses

Total Effects. For the skill-focused model, skill level was a significant predictor of performance, β = 54.89, p < .001 (i.e., the total effect, c, of skill on performance). Also, for the extraneous focus model, skill level was a significant predictor of performance, β = 51.28, p < .001 (i.e., total effect, c).

Workload. For the skill-focused model, the bootstrapping procedure (1000 samples) revealed a direct effect (c' = 44.98, SE = 8.63) 95% CI = (27.43, 62.53), and an indirect (i.e., mediation) effect (ab = 9.91; SE = 5.45), 95% CI = (1.53, 22.52). Thus, the inclusion of workload in the mediation model greatly reduced the direct effect of skill level on performance, but this relationship remained significant. Therefore, workload partially mediated the effect of skill level on performance during the skill-focused dual-task. Similarly, for the extraneous focus model, the bootstrapping procedure (1000 samples) revealed a direct effect (c' = 40.95; SE = 9.22) 95% CI = (22.20, 59.71), and an indirect effect (ab = 10.32; SE = 5.33), 95% CI = (2.91, 25.282). As per the skill-focused mediation model, the inclusion of workload greatly reduced the direct effect of skill level on performance, but this relationship remained significant. Similar to the skill-focused model, workload partially mediated the effect of skill level on performance during the extraneous focus dual-task.

Mental Demand. For the skill-focused model, the indirect effect of mental demand on performance was non-significant, 95% CI = (-.76, 12.49). For the extraneous focus model, however, the bootstrapping procedure (1000 samples) revealed a direct effect (*c'* = 40.99; *SE* = 9.39) 95% CI = (21.89, 60.88), and an indirect effect (*ab* = 10.29; *SE* = 5.41), 95% CI = (2.44, 24.11). The inclusion of mental demand greatly reduced the direct effect of skill level on performance in the extraneous focus model, but this relationship remained significant. Therefore, mental demand partially mediated the effect of skill level on performance during the extraneous focus dual-task.

Physical Demand. For the skill-focused and extraneous focus models, the indirect effect of physical demand on performance were non-significant, 95% CI = (-.74, 13.69) and 95% CI = (-.79, 16.76), respectively.

Temporal Demand. For the skill-focused model, the bootstrapping procedure (1000 samples) revealed a direct effect (*c'* = 43.60; *SE* = 8.89) 95% CI = (25.53, 61.68), and an indirect effect (*ab* = 11.29; *SE* = 4.93), 95% CI = (3.07, 22.97). Thus, the inclusion of temporal demand greatly reduced the direct effect of skill level on performance in the skill-focused model, but this relationship remained significant. Therefore, temporal demand partially mediated the effect of skill level on performance during the skill-focused dual-task. Similarly, for the extraneous focus model, the bootstrapping procedure (1000 samples) revealed a direct effect (*c'* = 41.03; *SE* = 8.95) 95% CI = (22.83, 59.23), and an indirect effect (*ab* = 10.25; *SE* = 5.42), 95% CI = (2.71, 24.95). As per the skill-focused mediation model, the inclusion of temporal demand greatly reduced the direct effect of skill level on performance, but this relationship remained significant. Similar to the skill-focused model, temporal demand partially mediated the effect of skill level on performance during the extraneous focus dual-task.

Performance. For the skill-focused and extraneous focus models, the indirect effect of perceived performance on performance were non-significant, 95% CI = (-.22, 18.03) and 95% CI = (-1.65, 3.16), respectively.

Effort. For the skill-focused model, the indirect effect of effort on performance was non-significant, 95% CI = (-1.44, 1.48). For the extraneous focus model, however, the bootstrapping procedure (1000 samples) revealed a direct effect (c' = 44.78; SE = 8.94) 95% CI = (26.60, 62.97), and an indirect effect (ab = 6.49; SE = 4.41), 95% CI = (7.38, 19.07). Thus the inclusion of effort greatly reduced the direct effect of skill level on performance in the extraneous focus model, but this relationship remained significant. Therefore, effort partially mediated the effect of skill level on performance during the extraneous focus dual-task.

Frustration. For the skill-focused model, the bootstrapping procedure (1000 samples) revealed a direct effect (c' = 46.38; SE = 8.81) 95% CI = (28.45, 64.30), and an indirect effect (ab = 8.51; SE = 5.97), 95% CI = (.23, 26.59). Thus the inclusion of frustration reduced the direct effect of skill level on performance in the skill-focused model, but this relationship remained significant. Therefore, frustration partially mediated the effect of skill level on performance during the skill-focused dual-task. Similarly, for the extraneous focus model, the bootstrapping procedure (1000 samples) revealed a direct effect (c' = 42.85; SE = 9.11) 95% CI = (24.31, 61.38), and an indirect effect (ab = 8.43; SE = 4.17), 95% CI = (2.23, 20.48). Thus the inclusion of frustration reduced the direct effect of skill level on performance in the extraneous focus model, but this relationship remained significant. Subsequently, frustration partially mediated the effect of skill level on performance during the extraneous focus dual-task.

Discussion

A large body of dual-task research has examined the effect of skill-focused and extraneous focus secondary tasks on primary task performance across skill levels (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock & Carr, 2001; Beilock & Gray, 2012; Castaneda & Gray, 2007; Gray, 2004; Suss & Ward, 2010). These studies have helped clarify the mode of attention most beneficial for successful primary task performance based on current skill level. To further our understanding of this relationship, we integrated a psychometric tool (i.e., NASA-TLX) to assess the potency of workload as a contributing psychological mechanism. Thus, the primary purpose of this study was to determine if the skill level on performance relationship during extraneous and skill-focused dual-tasks was occurring through the various workload demands each secondary task requires. We found that participants' primary and secondary task performances, regardless of skill level, were significantly greater during the extraneous focus compared to skill-focused dual-task. While these findings are consistent with typical higher-skilled performers, it is inconsistent with typical lower-skilled performance during dual-tasks (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Wierenga, & Carr, 2002; Gray, 2004). The increased secondary task error rate and increased workload during the skill-focused condition for all participants provides some explanation of the effects, however, they do not fully explain why lower-skilled participants found this condition more difficult. We suspect that these findings may be a partial reflection of the specific instructions used in the skill-focused manipulation (i.e., to focus on the trigger finger). Although the secondary task literature has shown skill-focused attention as a facilitator of novice performance (e.g., Beilock & Carr, 2001), previous research has also shown that when attention is directed ‘via instruction’ toward an internal aspect of movement execution (as opposed to being directed externally) a detrimental effect on performance ensues, regardless of skill level (e.g., Wulf & Su, 2007). Variations in methodology used for dual-task research versus instructional manipulation research provide some explanation for this difference (see Castaneda & Gray, 2007).

Congruent with our performance predictions, our workload hypotheses were only partially supported. We found that, regardless of skill level, workload was significantly greater during the skill-focused dual-task compared to the extraneous focus dual-task. While this is what we expected for higher-skilled participants, it is not what we predicted for lower-skilled participants. Since we expected performance to be better and easier for the lower-skilled participants on the skill-focused task, we suspected lower perceptions of workload would be exhibited for lower-skilled participants during the skill-focused task. However, following the performance outcome data, this was not the case, suggesting that secondary task difficulty, as reflected in increased workload and increased secondary task error, primarily drove the observed effects.

Such a conclusion is supported by the mediation analyses, which followed our predictions that the relationship between skill level and performance was a function of perceived workload. Both mediation models revealed a significant indirect effect of skill level on performance, indicating that the causal relationship between skill and performance was partially mediated by workload. Hence, the connection between skill level and dual-task performance seems, in part, linked through the subjective resource demands these tasks require. These results can add to our knowledge of previous dual-task work (e.g., Gray, 2004) by providing an indirect explanation of the skill level on performance outcome relationship. For example, although novices have tended to perform better when performing under skill-focused (as opposed to extraneous) dual-task conditions (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Wierenga, & Carr, 2002; Gray, 2004), this effect may be driven, at least in part, by the task difficulty and (or) workload demands of the tasks used to manipulate attention.

Our exploratory analyses that decomposed the construct of workload (via subscales) were also fruitful as they provided new knowledge that can contribute to our understanding of the skill level on performance relationship during skill-focused and extraneous focus dual-tasks. Specifically, our results revealed significant skill level main effects for, mental demand, temporal demand, effort, and frustration, suggesting that these specific components of workload were most affected by skill level. Interestingly, no differences in physical demand or performance were observed for skill level, suggesting that this task required an equivalent amount of physical requirements, and both skill levels judged their performance equally. Our results also revealed significant attention condition main effects for mental demand, temporal demand, performance, and effort, all suggesting that the skill-focused condition required more of these resources. This is interesting as the primary tasks were identical, but when attention was shifted towards skill execution, as opposed to an extraneous distractor, participants' perceptions of mental and temporal demands and ratings of own performance and effort were most affected.

Our exploratory mediation analyses also provided unique results in that they provided information on the specific subcomponents of workload that most contributed to the skill level on performance relationship during both dual-tasks. We found that, during the skill-focused model, the temporal demand and frustration subscales revealed a significant indirect effect of skill level on performance, indicating that the causal relationship between skill and performance was partially mediated by these two subcomponents. This is unique as it provides us with which subjective perceptions are most affecting the skill level on performance relationship during skill-focused dual-tasks. It seems that changes in attentional focus affect participants' perceptions of the temporal component of the task which could be affecting their level of frustration. Future work may want to manipulate the timing of secondary auditory tones more rigorously to better understand this skill level on performance relationship. We also found unique results for the extraneous focus subscale mediation analyses. Specifically, we found that, during the extraneous focus model, the mental demand, temporal demand, effort, and frustration subscales revealed significant indirect effect of skill level on performance, indicating that the causal relationship between skill and performance was partially mediated by these four subcomponents. Unique to the skill-focused model, we see that mental demand and perceived effort play a stronger role in the skill level on performance relationship during extraneous focus dual-tasks. This could be, in part, to the relative inexperience of our participants who are shown to be more susceptible to performance decrements when asked to focus extraneously (e.g., Beilock & Carr, 2001). Taken together, we can see that the subscale of physical demand or perceived performance does not play a large role in the skill level on performance relationship during either type of dual-task, but now have a better understanding of which subscales primarily affect workload as a mediator.

What is not clear, however, is whether workload would differ markedly across skill-focused tasks (e.g., focusing on the foot while dribbling a ball versus focusing on the trigger finger while firing a weapon) or other extraneous focus tasks (e.g., tone counting versus tone identification). Future work using dual-task methodology should consider using a subjective measure of workload when assessing performance across different skill levels. This inclusion could provide further information needed to understand how attention affects performance across skill levels. Our data suggest that skill level alone does not fully explain the differences seen across dual-task research, but various perceptions of workload that dual-tasks require could be driving performance differences.

It is reasonable to suspect that our decision to use a median split as a means to define skill level could have influenced the current findings—especially with the absence of significant skill-based differences between attentional conditions. These methods have been used to good effect previously (e.g., golf putts made; Wright & Erdal, 2008), but we expect that more differentiable skill groups (in terms of practice, experience, etc.) would likely have resulted in stronger skill effects and (or) a skill-based interaction. To increase our understanding of the relationship between attention, workload, skill level, and performance, future research is needed to examine whether the current results are observed in individuals that are more distinguishable in skill (e.g., novices, experts). Furthermore, the findings from our temporal demand subscale raise an interesting question regarding the speed and accuracy in which participants responded to the secondary task challenges. Our results indicate that temporal demand is a significant contributor to the skill level on performance relationship during dual-tasks and warrants further work. Researchers could begin including microphones that measure the audible reaction times to secondary task demands to investigate any potential trade-offs between error rate and audible response time (see Kelly, Janke, & Shumway-Cook, 2010) and its association with temporal demand. In addition, more research is needed to determine whether dual-task manipulations directed towards different aspects of skill execution (i.e., position of the shoulder), and (or) different extraneous tasks, place different workload demands on participants and, therefore, change the relationship between skill and performance. Ideally, new manipulations could be introduced that permit the attentional focus effects to be observed without unduly increasing workload. Such research could provide us with a better theoretical understanding of the psychological mechanisms facilitating changes in performance when attentional demands are high.

Conclusions

In sum, this study illustrates how workload changes as a function of attentional focus in dual-tasks and skill levels. Even across a group of individuals with low to moderate levels of expertise on a particular motor task, attention directed towards an extraneous distractor resulted in substantially less workload than attention directed towards an aspect of skill execution. In line with previous research, attention directed internally toward skill execution appears to disrupt the fluidity of movement execution, perhaps through increases in perceived workload. To be more specific, internal or skill-focused attentional manipulations may redirect attentional resources that are needed for skill-execution in an inefficient manner as the body attempts to reorganize. Future research should continue to examine the effects of secondary task attentional manipulations on perceived workload and its subcomponents to fully understand the skill level on performance relationship.

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