

RESEARCH ARTICLE

Time Pressure and Attention Allocation Effect on Upper Limb Motion Steadiness

Sicong Liu¹, Robert C. Eklund², Gershon Tenenbaum¹

¹Department of Educational Psychology and Learning Systems, Florida State University, Tallahassee. ²School of Sport, University of Stirling, Scotland.

ABSTRACT. Following ironic process theory (IPT), the authors aimed at investigating how attentional allocation affects participants' upper limb motion steadiness under low and high levels of mental load. A secondary purpose was to examine the validity of skin conductance level in measuring perception of pressure. The study consisted of 1 within-participant factor (i.e., phase: baseline, test) and 4 between-participant factors (i.e., gender: male, female; mental load: fake time constraints, no time constraints; attention: positive, suppressive; order: baseline→→→test, test→→→baseline). Eighty college students (40 men and 40 women, $M_{age} = 20.20$ years, $SD_{age} = 1.52$ years) participated in the study. Gender-stratified random assignment was employed in a $2 \times 2 \times 2 \times 2 \times 2$ mixed experimental design. The findings generally support IPT but its predictions on motor performance under mental load may not be entirely accurate. Unlike men, women's performance was not susceptible to manipulations of mental load and attention allocation. The validity of skin conductance readings as an index of pressure perception was called into question.

Keywords: choking under pressure, ironic process, gender difference, skin conductance

Matthew Emmons, the U.S. Olympic marksman, had trouble with his last performance trial in the men's 50 m three-position rifle shooting event in three consecutive Olympic competitions (i.e., Athens 2004, Beijing 2008, London 2012). In 2004 he shot at another shooter's target. In 2008 and 2012, respectively, he earned scores of 4.4 and 7.6 (of 10.9) in his last attempts. If he had maintained his level of prior performance in the last shots in each competition, he would have brought home two gold medals and one silver medal. In London, he told the press that he was shaking so much on the last shot and he was telling himself "don't hold up, don't dress it up, just make it the best you can" immediately before pulling the trigger (D'Alessandro, 2012, paragraph 14).

Apparently, Emmons intuitively employed suppressive self-talk in performing this time-constrained task (i.e., averaging 75 s per shot), but the result was ironically different from his intent. Wegner (1994) elaborated on the possibility of this kind of outcome in his ironic process theory (IPT). In his view, an attentional control system needs at least two processes to maintain checks and balances. One memory process, the operator, must be in charge of producing the desired output, while the other, the monitor, runs a counter-intentional search to locate operator failures. For human beings, the operator requires substantial attentional resources to perform properly in exerting mental control because it is "conscious, effortful, and interruptible and performs the 'work' of mental control" (Wegner, 1997, p. 12). The monitor, however, requires few attentional resources

because it is "unconscious, less effortful, but uninterruptible as long as mental control is exerted" (Wegner, 1997, p. 12). Another critical term in IPT is *mental load*. The definitive function of mental load is to deplete availability of attentional resources (Wegner, 1994). According to Wegner (1994, 1998), mental load can take the form of time constraints, memory load (e.g., recall of digit strings), arithmetic calculation (e.g., counting backward from 1,000 by threes), distractions (internal or external), alcohol intake, and emotional loading (e.g., depressive mood). When mental load interferes with the operator by depleting the attentional resources, the unchecked monitor can sensitize the performer to counter-willed results because of its focus on the "nontarget" (Wegner, 1994, p. 41).

Choking under pressure is defined as "the occurrence of inferior performance despite individual striving and situational demands for superior performance" (Baumeister, 1984, p. 610). Baumeister (1986) interpreted *pressure* in the term as "any factor or combination of factors that increases the importance of performing well on a particular occasion" (p. 610). In this conceptualization, choking is not the individual's intended result given pressure, and thus its occurrence is one could be predicted by IPT. Although several theories/models have relevance to choking under pressure, only few main theoretical approaches deserve consideration here because of their shared underlying assumption with IPT; namely, that attention affects performance.

The first, distraction theory (Baumeister & Showers, 1986), posits that choking phenomenon occurs because the performer fails to allocate attention to and make good use of information critical to performance. Pressure plays the role of having performers become susceptible to distracters, and thus undermines their performance. The others, explicit monitoring theory (Beilock & Carr, 2001), self-focused model (Lewis & Linder, 1997), and the theory of reinvestment (Masters, 1992) share considerable commonality. All presuppose that choking emerges when performers tend to draw attention inward under pressure and follow a step-by-step process in skill execution. This step-by-step processing disrupts well-learned proceduralized performance that normally runs outside of conscious awareness. According to

Correspondence address: Sicong Liu, Department of Educational Psychology and Learning Systems, College of Education, Florida State University, 1114 W. Call Street, Tallahassee, FL 32306-4450, USA. e-mail: sl10e@my.fsu.edu

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the theory of skill acquisition (Anderson, 1982, 1983; Fitts & Posner, 1967), however, both approaches address only one facet of choking under pressure because their explanatory power is circumscribed by athletes' level of expertise. That is, distraction theory tends to provide a better explanation on choking by novices than by experts, whereas explicit monitoring theory (and similar theories) tends to do better in explaining choking among experts than novices. Furthermore, both distraction and step-by-step processing approaches involve unexplained links in their explanatory chains. Specifically, distraction theory does not offer the reason for novices' tendency to be distracted under pressure and explicit monitoring theory (and similar theories) goes no further than arguing that external pressure can dispose skilled performers to executing skills in a step-by-step fashion. IPT has a promise for accounting for these missing links by recognizing that suppression is an intuitive mental control strategy of human beings under stress (Wenzlaff & Wegner, 2000), and that an imbalanced share of task load between operator and monitor (due to careless suppression) would magnify the chance of ironic result (Wegner, 1994).

The most challenging part in understanding IPT is how suppression affects the attention allocation process, especially in the presence of mental load. Because the operator directs an individual's attention toward the target and monitor checks for nontarget, their attention allocation processes can serve complimentary purposes (Wegner, 1994). Therefore, when focusing attention in a positive way, such as steady the grip of rifle, the only objective for operator is to direct efforts on stabilizing the grip but monitor would undertake all the rest including searching for events that are in direct opposition to the operator (e.g., shaking of the grip) and numerous tangential events (e.g., a voice from audience). Such an asymmetry in attention allocation dictates that operator has a much easier task than monitor, which helps to ensure that the functional predominance of operator over monitor may continue even under mental load. Things are quite different, however, when attention is directed in a suppressive manner, such as trying not to shake in holding the rifle. In this case, the easier task of searching a shake is shifted to monitoring process whereas the operating process is placed in charge of the opposing event (i.e., stop the shaking) and controlling tangential awareness (e.g., current ranking in shooting event). The asymmetry is exacerbated when the presence of mental load consumes attentional resources needed by the operator. It is by the interaction of suppressive attention and mental load that the operator becomes the underdog in competing with the monitor, which gives rise to counterwilled results (Wegner, 1994).

Support for IPT has been observed in a variety of motor tasks, such as golf putting (Beilock, Afremow, Rabe, & Carr, 2001; Binsch, Oudejans, Bakker, & Savelsbergh, 2009; Wegner, Ansfield, & Pilloff, 1998), dart throwing (Oudejans, Binsch, & Bakker, 2013), soccer penalty shooting (Bakker, Oudejans, Binsch, & Kamp, 2006; Binsch

et al., 2009, 2010), and static balancing (Dugdale & Eklund, 2003). However, previous findings on mental load are mixed. For example, Wegner et al. found evidence to support the ironic-result enhancing view of mental load on tasks of golf putting, whereas de la Peña, Murray, and Janelle (2008) did not in Experiment 1. Oudejans et al. showed that mental load predisposed participants to ironic error in a dart-throwing task. However, Dugdale and Eklund only observed a descriptive trend consistent with IPT contentions on mental load during performance of a static balancing task but it was nonsignificant ($p < .17$; $\eta_p^2 = .12$). In other studies (i.e., Bakker et al., 2006; Binsch et al., 2009, 2010) mental load took the form of time constraints on task execution (i.e., taking soccer penalty kicks within about 1 s); however, mental load has not been considered a factor in the studies' statistical analyses. It is meaningful, thus, to clarify previous inconsistent findings on mental load through further investigation, especially when considering the fact that some forms of mental load (e.g., time constraints) represent a core feature in competitive sports (Janelle, 1999).

Gender differences may be another interesting factor when testing IPT in the motor skill domain, given the evidence that women may be better than men in many types of tasks involving suppression, including selective attention and motor inhibition and impulse control (Bjorklund & Kipp, 1996). Moreover, some evidence suggests that women are better than men in manual dexterity tasks (Nicholson & Kimura, 1996; Tiffin & Asher, 1948) although the evidence is not unequivocal (Peters & Campagnaro, 1996). Nevertheless, very few investigators studying IPT in motor task have considered gender differences in their research. They either did not include gender factor in the testing model (Beilock et al., 2001; Binsch et al., 2009) or employed a single gender sample (Bakker et al., 2006; Binsch et al., 2010; Dugdale & Eklund, 2003). Wegner et al. (1998) and de la Peña et al. (2008) were the only studies paying attention to gender as a factor. Wegner et al. observed a marginally significant difference ($p < .06$) between female and male in golf putting task (Experimental 1), but nonsignificant differences in pendulum holding task (Experiment 2). For de la Peña et al. no gender differences were evident in a golf putting task. Considering that gender is under-investigated in this area, this study aimed to further explore whether women and men differ in such a motor task featuring attention suppression and limb dexterity.

Going beyond of using cognitive and behavioral variables as outcome measures, Wegner, Broome, and Blumberg (1997) further employed a physiological indicator in their experiments testing IPT. For instance, they found that participants experienced increasing skin conductance level (SCL) as a consequence of purposeful relaxation under high mental load. El-Sheikh, Keiley, and Hinnant (2010) argued that SCL readings are "markers of the activity of the sympathetic nervous system (SNS)" (p. 116), and the main function of SNS is to facilitate the fight or flight behavior in

stressful situations. Following this line of reasoning, some researchers believe that SCL is a measure of activation–arousal level and nothing more (Potter & Bolls, 2012; Salazar et al., 1990; Tremayne & Barry, 2001). However, by enumerating multilayered control pathways in the brain (i.e., contralateral cortical and basal ganglion, hypothalamus and limbic system, as well as reticular formation), Dawson, Schell, and Fillion (2000) argued that SCL could be markers of other functions, such as affective processes and attention. Therefore, to help explore SCL’s potential as an indicator of perceived pressure, we also examined whether SCL could index an individual’s pressure perception by comparing it to participants’ self-report of pressure.

The purpose of present study was twofold. First, IPT was tested using a new task of upper limb motion steadiness. This task shares some commonalities with tasks such as dart throwing (Oudejans et al., 2013) and golf putting (Beilock et al., 2001; Binsch et al., 2009; Wegner et al., 1998), but at the same time is unique in terms of its perceptuomotor skill requirements. In the present research more attention was given to mental load and to potential gender differences than to earlier research testing IPT. A secondary purpose was to test the notion that SCL can be used as a valid index of pressure perception. The steadiness task was chosen to simulate the event of shooting and the main components of IPT, attention (positive vs. suppressive) and mental load (under no time constraints vs. under time constraints) were manipulated between groups. To meet our secondary study purpose, data were collected on both reflective self-reported pressure levels and SCL during performance. We expected that participants’ performance would decline under the condition of suppressive attentional focus and high mental load to a greater extent than other factorial combinations of attention allocation and mental load level. We also expected that women would demonstrate superior performance to men in the task, and that the superiority would be more obvious when performing with a suppressive attentional focus. Finally, SCL was hypothesized to be indicative of an individual’s pressure perception by demonstrating a result pattern similar to that of the self-reported pressure ratings.

Method

Participants

Undergraduate students ($n = 111$) from a southeastern U.S. public university participated in the study. These participants presented evidence of no disability or deformity of vision and upper limbs that might impede their ability to perform on the designated task. Data from 15 men and 16 women were not entered for analysis because of a priori inclusion criteria outlined in the Results section. For the remaining 80 participants (40 men and 40 women, $M_{age} = 20.20$ years, $SD_{age} = 1.52$ years), self-reporting indicated that 10% were left-handed ($n_{left} = 8$) and 90% were right-

handed ($n_{right} = 72$). All the participants (including those excluded from analysis) gave informed consent before participation and the protocol of the study was approved by the ethics committee of local research institute.

Apparatus

Motion steadiness. The limb motion steadiness apparatus (BD-II-304A, Beida Jade Bird, Beijing, China; see Figure 1) enables to measure an individual’s upper limb motion steadiness via three methods (i.e., curvilinear track, linear wedge track, and holes). In the present study, participants used their dominant hand to perform the symmetric curvilinear track with a stylus wired to the main device box. The starting point of the motion steadiness task was the midpoint of the curvilinear track, which is 10 mm wide. Both extreme ends of the curve have a width of 2 mm. The narrowing transitions from the center to the distal ends are gradual. The diameter of the stylus tip is 1.5 mm. If the stylus touches the bottom of the track (which is part of the bottom steel layer of the device), a red bulb at the upper-center of the box lights up as a warning sign. When the stylus touches the side of the curvilinear track (which is part of the surface layer of the device), a beeping sound is made and the reading of the path’s width at that point is recorded by reference to the scale on the track’s sides. The median performance score (i.e., width median) of the task for each block was used as the representative value for that particular block. The median value was chosen to avoid the influence of extreme values from each participant’s performance distribution. Extreme values are often spotted in an individual’s performance distribution, and they are apparently more on the side that has larger width values (i.e.,

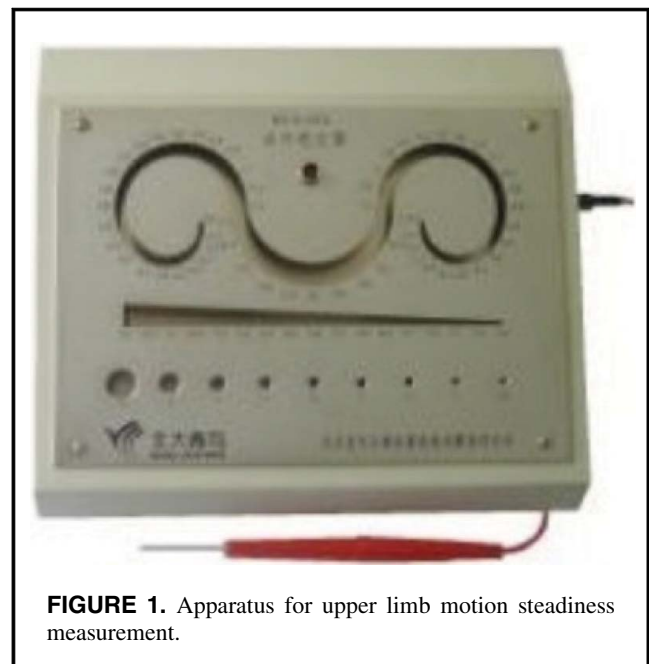


FIGURE 1. Apparatus for upper limb motion steadiness measurement.

participants touch the side of the path near the start point, which is supposed to be easy to pass) than the other side with smaller width values (i.e., participants go much further along the path beyond the point they usually touch).

Digital camera. A digital video camera (VIXIA HFM40, Canon, Japan) mounted on a tripod was used to record participants' performance on the motion steadiness apparatus. It serves the purpose of minimizing the influence of experimenter's presence on the participants. Participants' performance on the motion steadiness apparatus was thus read from the video after task completion.

Skin conductance. SCL device (SA9309M, Thought Technology, Montreal, Canada) gauged participants' hyperdermal activities during their task performance. This device consists of two sensors connected to a laptop (to generate and record the readings of the sensor) via a coder box (ProComp Infiniti, Thought Technology). The SCL sensors are placed on the second phalanges of index and middle fingers of the participants' subdominant hand (Caterini et al., 1995).

Survey. A short post-experimental survey was prepared for participants. It consisted of three 7-point Likert-type scale questions. The first question was used as a manipulation check of attentional focus by asking participants, "After you repeated the phrase ("Don't shake"; or alternatively "Go steady"), to what extent did you remember it, or keep hearing it in your mind while performing the task?" The attentional focus manipulation was only considered effective when participants' ratings were ≥ 5 as larger ratings indicated a stronger attentional focus (cf. Vuilleume & Nafati, 2007). The second question asked participants' to rate how much pressure they felt during their performance by answering, "Please rate the amount of pressure you felt during the nonverbal session of the task." The third question was the same as the second question except that "nonverbal" was replaced by "verbal" in the item stem. Participants rated on the second question immediately after they finished the baseline task block and they answered the first and third questions together as soon as they accomplished the manipulated block of task.

Finally, the experimenter sat behind the participant chair. The experimenter's role during the experiment was to instruct participants, record their performance duration using a stopwatch, and ostensibly to inform participants when they violated the time constraints.

Design

The study involved one within-participant factor (i.e., phase: baseline, test) and four between-participant factors (gender: male, female; mental load: fake time constraint, no time constraint; attention: positive, suppressive; order: baseline \rightarrow \rightarrow test, test \rightarrow \rightarrow baseline). Thus, it is a $2 \times 2 \times$

$2 \times 2 \times 2$ mixed experimental design. Phase was introduced to control for participants' genetic tendency in upper limb stability and its two subcomponents were counterbalanced by order to control for learning and fatigue effect. Random assignment stratified by gender and order was employed in placing participants into the four groups resulting from the factorial combination of attention and mental load. These groups were, specifically, (a) high mental load suppressive self-talk (HLSS), (b) high mental load positive self-talk (HLPS), (c) low mental load suppressive self-talk (LLSS), and (d) low mental load positive self-talk (LLPS).

Task Manipulation

A fake time constraint was used to create a high mental load condition due to its ecological validity in many sport endeavors. Participants in the low mental load condition were told that there was no time limit to complete the task. In contrast, participants in the high mental load group were told that there was a time constraint of 9 s to complete the task. In addition, these participants were also informed that their adherence to the time constraints (e.g., no or few 9 s violation counts) would increase their chance of receiving a gift card. Pilot study testing indicated that 9-s period was shorter than the usual performance duration for most participants on the task, and hence it was considered a challenge to the participants. The gift cards played a role of an extrinsic reward. It was intended to strengthen the effect of time constraint instruction.

Self-talk was employed to control participants' attentional focus. Participants were instructed to repeat out loud the cue words appropriate for the condition (i.e., "Don't shake" or "Go steady") for 10 s before they started to perform the task, and to "try to hear the cue words" after they started performing. Furthermore, all participants were instructed that they should do their best in each trial.

Procedure

All the participants registered to join the experiment through an online subject pool system in return for one credit in their coursework. The researcher scheduled specific appointment times with these participants and the study was conducted in a laboratory located in an on-campus location.

All participants were given identical instructions from a preprepared script when they arrived at the laboratory. Participants were invited to read and sign a consent form. If they agreed to participate, they were asked for demographic information. They were told that the study was intended to examine the relationship between skin conductivity and hand motion steadiness, and that their goal in the task was to do their best in the steadiness test. Then, about 5 min were spent on attaching SCL electrodes to participants' fingers and having participants practice 10 trials of the main task using their dominant hand. After its completion,

participants were instructed to choose one direction of the symmetric curvilinear track (i.e., either go left or go right) in the main device for their performance trials. Once chosen, the direction could not be altered across trials.

After assignment to an experimental group, each participant was then asked to complete two blocks of 10 trials on the task. A 30-s rest period was employed between consecutive trials as well as a 5-min rest period between the blocks. In the baseline block, there was no manipulation exerted upon participants. Relevant manipulations were addressed to participants in the test block. The task began only after participants demonstrated a full grasp of the meaning of the instruction by correctly telling the experimenter the task goal (i.e., with or without time constraint) as well as the correct self-talk cue words. Manipulations of the four groups during test blocks are described subsequently:

1. HLSS: Participants were told that they needed to do their best in each trial of task within 9 s so that their chances of winning the rewards would not be reduced. In addition, they were asked to keep rehearsing aloud “Don’t shake” for 10 s, while subsequently continuing to try to hear the phrase while performing.
2. HLPS: Participants were told that they needed to do their best in each trial of task within 9s so that their chances of winning the rewards would not be reduced. In addition, they were asked to keep rehearsing aloud “Go steady” for 10 s, while subsequently continuing to try to hear the phrase while performing.
3. LLSS: Participants were told that they needed to do their best in each trial of task and there was no time limit and no reward was mentioned to them. In addition, they were asked to keep rehearsing aloud “Don’t shake” for 10 s, while subsequently continuing to try to hear the phrase while performing.
4. LLPS: Participants were told that they needed to do their best in each trial of task and there was no time limit and no reward was mentioned to them. In addition, they were asked to keep rehearsing aloud “Go steady” for 10 s, while subsequently continuing to try to hear the phrase while performing.

For participants assigned to high mental load condition, experimenter did not interrupt their performance when they went beyond 9 s. However, they received a feedback of their performance duration after the trial ended. They were prompted to follow the 9 s rule to increase their chance of receiving rewards. Performance accuracy and duration were measured for each task trial for all participants. Also, participants’ SCL readings were accumulatively recorded for each trial block, respectively, only during the time when participants were performing the task. Immediately after task completion, each participant was asked to fill out the postexperimental survey. SCL electrodes were subsequently detached from participants during this period. The

debriefing script of the study was emailed to participants at the end of data collection. They were offered a chance to ask questions and, because minor deception was involved in the protocol, asked to decide whether their data could be used for the current research. None of the participants declined the use of their data for analyses of the investigation.

Analysis

The study used SPSS 18.0 (Chicago, IL) for the following statistical analysis. First, descriptive statistics such as group mean and standard deviation values were calculated for each variable. Second, manipulation check of mental load was performed by testing pressure ratings using a repeated measures (RM) analysis of variance (ANOVA). Then, mental load, attention, gender, and order were input as between-participant factors; the two width medians from the baseline and test block, respectively, were input as the within-participant factor, phase. An RM ANOVA figuring these factors was performed to test the main hypotheses of the present study. Order was included as a factor in the statistical analyses to strengthen our causal inferences (Gelman & Hill, 2007). Independent and paired *t* tests were later run to further compare subgroup results. Lastly, another RM ANOVA was performed (in the same way as pressure ratings) to test SCL as a measure of an individual’s perceived pressure level.

Results

Manipulation Check

Before manipulation check, the values of width median (of each block), task-completion time, SCL, pressure rating, and attentional focus rating were calculated.¹ As only participants who rated ≥ 5 on the attentional focus question were included in the study, the manipulation on participants’ attentional focus ($M = 5.60$, $SD = 0.67$) was considered successful. A Gender \times Attention \times Mental Load \times Order \times Phase RM ANOVA was performed to test the mental load manipulation by using posttask pressure ratings as the dependent variable. A significant main effect for phase, $F(1, 71) = 15.61$, $p < .001$, $\eta_p^2 = .18$, and a significant phase by mental load interaction, $F(1, 71) = 5.63$, $p < .03$, $\eta_p^2 = .06$, were observed. Therefore, participants assigned to high mental load condition experienced larger increase of pressure perception from baseline to test block ($M_{\text{Test}} - M_{\text{baseline}} = 1.05$) than did those assigned to low mental load condition ($M_{\text{Test}} - M_{\text{baseline}} = 0.30$), $t(78) = 2.23$, Cohen’s $d = .50$. This indicates that the mental load manipulation was successful.

Group Difference

Prior to testing any group differences, a preliminary analysis was conducted to test the within-participants

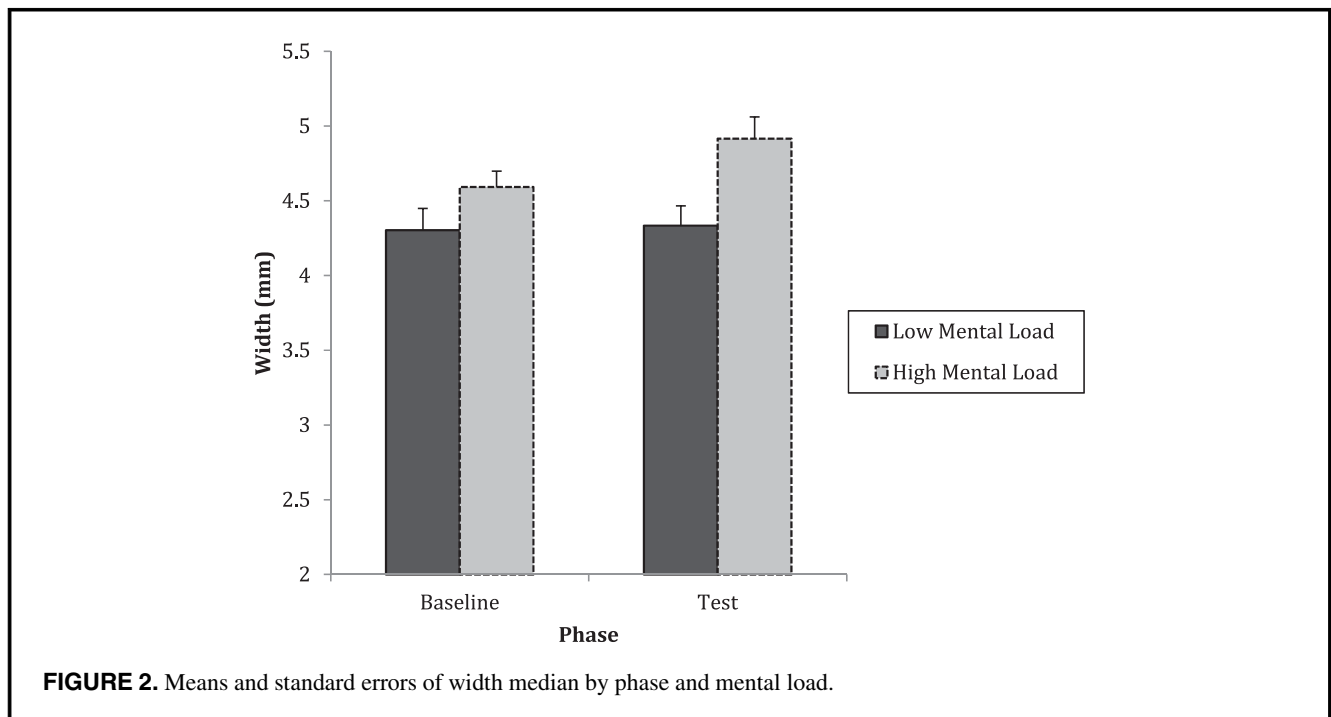


FIGURE 2. Means and standard errors of width median by phase and mental load.

performance difference across trials in baseline block and test block, respectively (cf. Dugdale & Eklund, 2003). The results revealed nonsignificant ($p > .05$) differences, and thus revealed neither learning effects nor fatigue effects on the performance of each block of trials.

The Gender \times Attention \times Mental Load \times Order \times Phase RM ANOVA revealed significant main effect for phase, $F(1, 71) = 6.19, p < .02, \eta_p^2 = .08$, and mental load, $F(1, 71) = 6.65, p < .01, \eta_p^2 = .09$. Participants performed worse in test block ($M = 4.62, SD = 0.92$) than in baseline block ($M = 4.44, SD = 0.81$), paired sample $t(79) = 2.24, p < .03$, Cohen's $d = .20$, and they also performed worse under high mental load ($M = 4.75, SD = 0.80$) than under low mental load ($M = 4.32, SD = 0.88$), $t(78) = 2.29, p = .01$, Cohen's $d = .52$.

A significant phase by mental load interaction, $F(1, 71) = 4.20, p < .04, \eta_p^2 = .06$, was observed as well as a phase by attention interaction, $F(1, 71) = 4.50, p < .04, \eta_p^2 = .06$. Regarding the phase by mental load interaction (see Figure 2),² participants' performance on baseline and test block remained similar ($M_{\text{Baseline}} = 4.30, SD_{\text{Baseline}} = 0.92$; $M_{\text{Test}} = 4.33, SD_{\text{Test}} = 0.84$) under low mental load, paired sample $t(39) = -0.27, p < .79$. In contrast, participants from the high mental load group performed worse in the test block ($M = 4.92, SD = 0.92$) than in the baseline block ($M = 4.59, SD = 0.67$), paired sample $t(39) = 3.09, p < .004$, Cohen's $d = .40$. As for the phase by attention interaction (see Figure 3), the group rehearsing "Go steady" had similar performance on test block ($M = 4.59, SD = 0.90$) and baseline block ($M = 4.56, SD = 0.85$), paired sample $t(39) = 0.25, p < .80$. However, a performance difference

was observed between the two blocks for participants rehearsing "Don't shake." Specifically, their performance deteriorated in the test block ($M = 4.66, SD = 0.95$), compared to that of baseline block ($M = 4.33, SD = 0.77$), paired sample $t(39) = 2.79, p < .008$, Cohen's $d = .36$.

Only a trend was observed for attention by mental load by phase interaction, $F(1, 71) = 2.60, p < .11, \eta_p^2 = .04$. Therefore, our prediction on mental load was not fully supported. Changes in mean performance of the four groups from baseline block to test block (see Figure 4) suggest that HLSS ($M_{\text{Test}} - M_{\text{baseline}} = 0.36$), paired sample $t(19) = 2.06, p < .05$, Cohen's $d = .38$; HLPS ($M_{\text{Test}} - M_{\text{baseline}} = 0.29$), paired sample $t(19) = 2.38, p < .03$, Cohen's $d = .44$; and LLSS ($M_{\text{Test}} - M_{\text{baseline}} = 0.30$), paired sample $t(19) < 1.83, p = .08$, Cohen's $d = .34$, groups all experienced performance declines. However, LLPS group ($M_{\text{Test}} - M_{\text{baseline}} = -0.23$), paired sample $t(19) = -1.63, p < .12$, Cohen's $d = -.30$, suggested a potentially meaningful performance improvement.

The RM ANOVA also indicated that the within-participant effect of phase by gender interaction reached statistical significance, $F(1, 71) = 8.67, p < .004, \eta_p^2 = .11$. However, no other significant interactions involving gender were observed. Even though male and female participants had similar performance scores for the baseline block ($M_{\text{Male}} = 4.47, SD_{\text{Male}} = 0.83$; $M_{\text{Female}} = 4.42, SD_{\text{Female}} = 0.81$), $t(39) = 0.27, p < .39$, their task performance differed in the test blocks (see Figure 5). Specifically, female participants had a similar performance ($M_{\text{Female}} = 4.39, SD_{\text{Female}} = 0.87$) to their baseline block, paired sample $t(39) = -0.32, p < .75$, whereas male participants performed worse in test

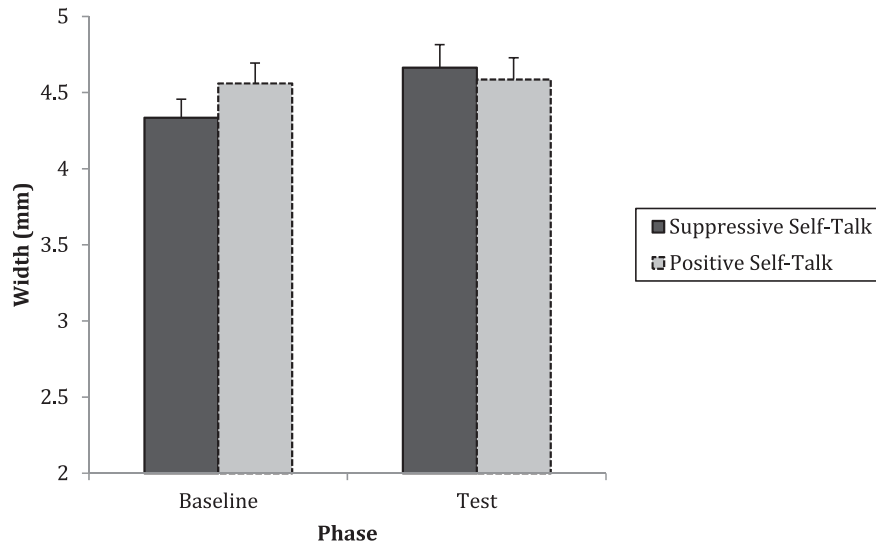


FIGURE 3. Means and standard errors of width median by phase and attention (self-talk).

block ($M_{\text{Male}} = 4.86$, $SD_{\text{Male}} = 0.92$) than in baseline block, paired sample $t(39) = 3.38$, $p < .002$, Cohen's $d = .44$.

Comparison Between SCL and Pressure Ratings

The mean SCL readings of the time period for the baseline and test blocks, respectively, were input as dependent variable in the Gender \times Attention \times Mental Load \times Order \times Phase RM ANOVA. A significant main effect for phase was observed, $F(1, 71) = 3.39$, $p < .05$, $\eta_p^2 = .053$, as well as a significant phase by order interaction, $F(1, 71) = 28.57$, $p < .001$, $\eta_p^2 = .29$. The phase by mental load interaction was not significant, $F(1, 71) = 1.28$, $p = .26$, $\eta_p^2 = .02$, although a trend compatible with expectation was observed (see Figure 6). Overall, a substantial similarity between SCL and pressure ratings was not observed.

Discussion

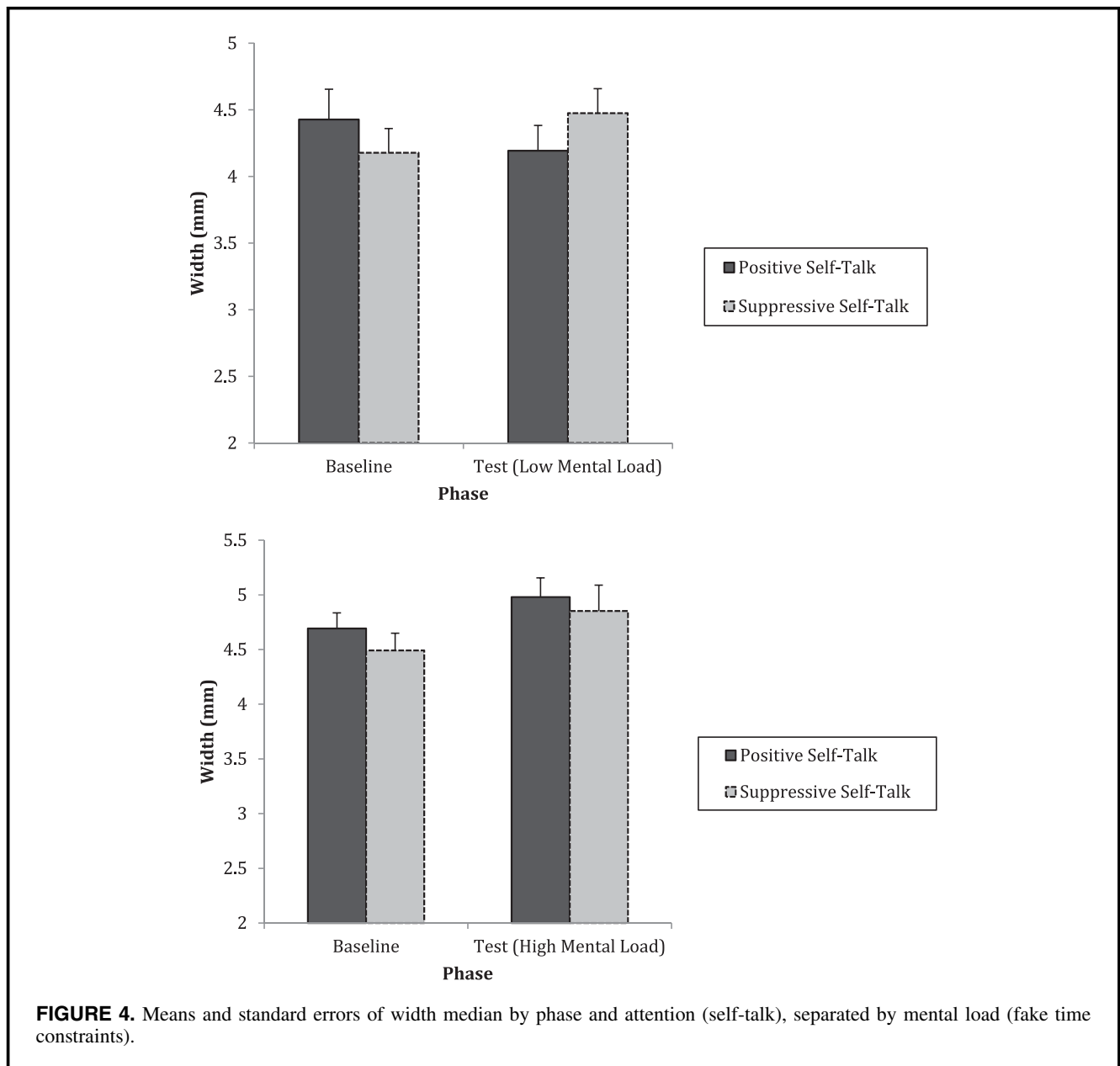
Ironic Process and Choking

In the present study, we aimed at testing IPT using an upper limb motion steadiness task. We were particularly interested in examining the effect of mental load on motor performance under conditions of positive or suppressive attention allocation. The analysis revealed nonsignificant ($p < .11$) Attention by mental load by phase interaction effect, even though the follow-up t tests suggested different performance changes between groups. Specifically, we found that some performance decline, or choking, occurred for participants using the suppressive self-talk (“Don’t shake”), whereas participants using positive self-talk (“Go steady”) demonstrated a divergent pattern of task performance depending on the level of mental load. Specifically, an

individual’s repeating “Go steady” was performance-enhancing under low mental load. It did not, however, help under high mental load, and participants’ performance was undermined in a way that was similar to the participants using suppressive self-talk. This result is generally consistent with what was observed in the Dugdale and Eklund’s (2003) study, and thus does not provide clear support for conclusions from either Wegner et al.’s (1998) or de la Peña et al.’s (2008) Experiment 1 as mentioned in the introduction.

The mechanism through which ironic process manifests itself in motor performance is not well understood. One difficulty may be that choking is, theoretically, the counter-willed result at a behavioral level, whereas those ironic thoughts focused by Wegner (1994) are cognitive level observations. Regarding this, understanding the link between suppressive attention and key performance-related behavioral variables would be useful. For example, some researchers (Bakker et al., 2006; Binsch et al., 2009, 2010) found that, in aiming tasks, participants receiving suppressive attention manipulations often visually fixated on the to-be-avoided area and demonstrated decreasing performance. Given the consistent findings that a longer fixation on the target before execution is needed for successful motor performance than unsuccessful performance (Mann, Williams, Ward, & Janelle, 2007), it is not surprising that suppression can undermine motor performance by deteriorating the visual aiming process.

The other difficulty is related to understanding the construct of mental load. Some researchers have argued, for instance, that the key of ironic processing lies in the frequency of thought suppression, rather than the mental load (Beilock et al., 2001; Macrae, Bodenhausen, Milne, & Jetten, 1994). For example, when instructed to do suppressive imagery (and positive imagery, respectively) before every

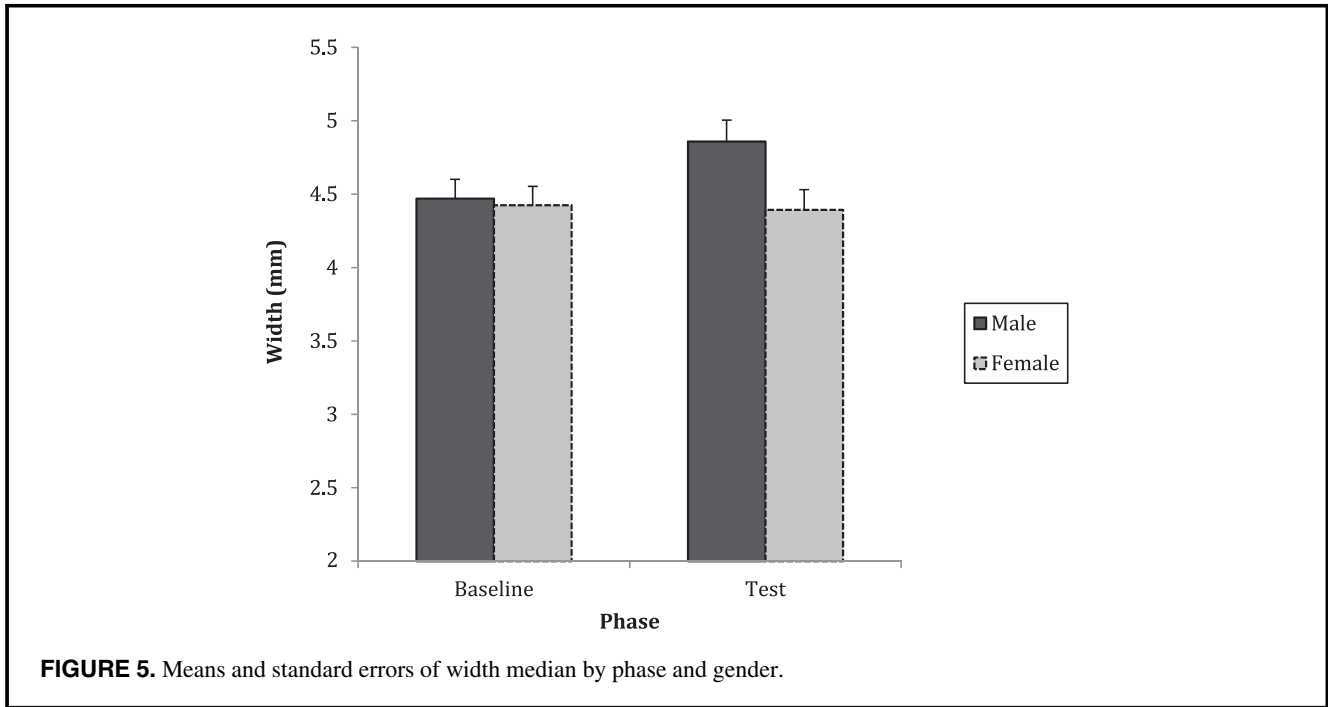


trial of golf putting task, participants' performance was worsened (and enhanced, respectively) compared to themselves when instructed to do imagery every third trials. Our low mental load groups (i.e., LLSS and LLPS) received similar manipulations to Beilock et al.'s participants with respect to instruction frequency, attentional focus, as well as absence of mental load. What is more important, they demonstrated the similar performance outcomes, and thus supported the frequency-oriented view.

It is not clear why the addition of mental load failed to distinguish participants rehearsing "Don't shake" from those rehearsing "Go steady" in our study. One reason may be that the cue words of attentional focus are not the participants' own but imposed by the researchers (Wenzlaff & Wegner, 2000). In sports competition, athletes often use

habitual self-talk to cope with stressful situations. In Emmons's case, the perception of enormous pressure may have heightened the strength and frequency of his suppressive attention because this suppression is part of his coping strategy. However, if the self-talk cue words fail as a spontaneous coping process, they will probably not be enhanced by mental load. From such a perspective, these arguments can be tested in the future by involving measurements of thought suppression frequency, such as those introduced by Wenzlaff and Wegner. As well, the prediction of mental load's differential effects on instructed and spontaneous suppression could also be studied.

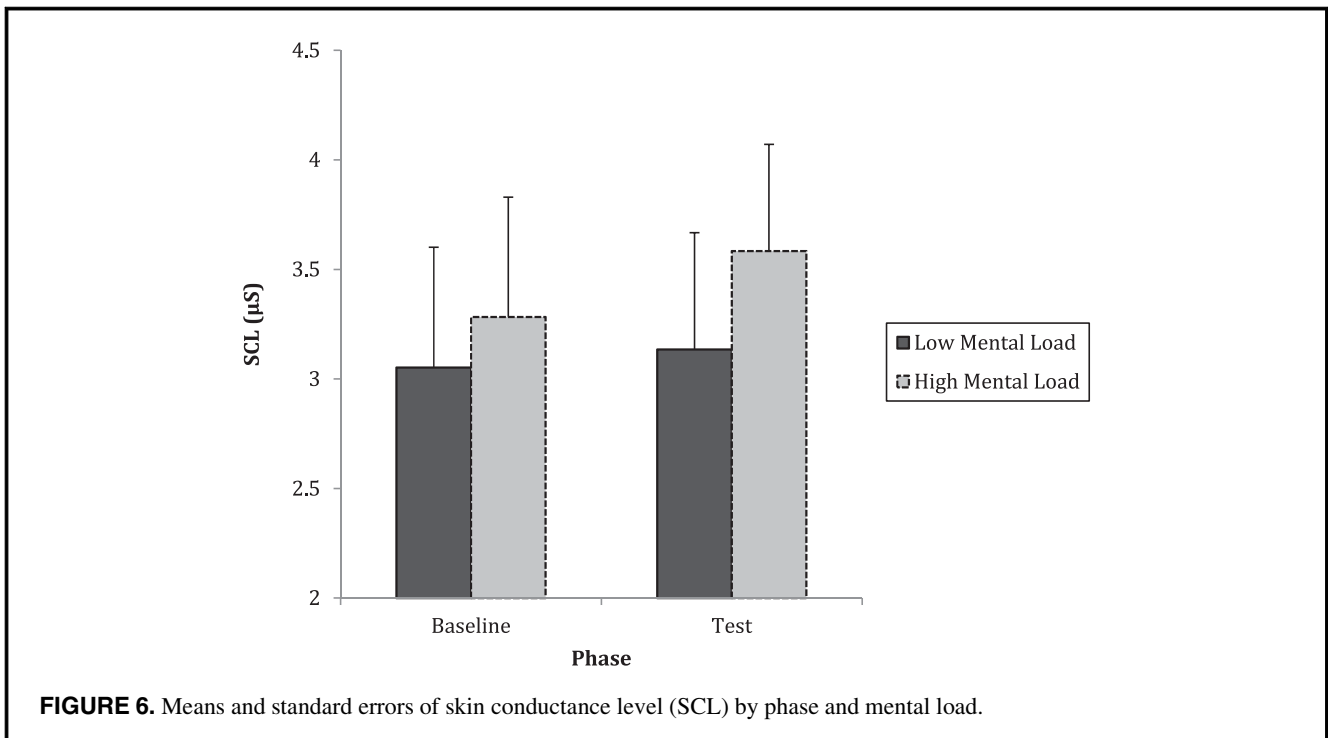
Moreover, mental load may affect motor performance through other paths than ironic processing. For example, mental load may undermine motor performance by



distracting novices, a derivative of distraction theory and theory of skill acquisition. In the present study, all the participants performed the upper limb task for the first time, and thus it is reasonable to assume that they were not skilled performers of this task. Even though subvocally rehearsing cue would consume certain amount of attentional resources during task performance, this cost should be relatively minor compared to the effect of attention

allocation (directed by self-talk) in low mental load condition. The LLPS group, for example, still managed to improve task execution.

Nevertheless, the situation was different when mental load (i.e., time constraint) was added to the task manipulation. The participants performing under the time limit completed the task in about half the time (5.42 s vs. 11.91 s) of counterparts performing without the time constraint. In



addition, 21 of the 31 participants filtered out of the study for failing to adhere to the self-talk cue words had experienced the high mental load manipulation. It may have been that both HLSS and HLPS participants choked because the distracting effect of the time manipulation was more powerful than its effect in enhancing ironic process. If this was the case, IPT may not be a sufficient replacement for distraction theory and the theory of skill acquisition. Future researchers must address this ambiguity by testing whether skill level moderates the interaction between mental load and thought suppression. Beyond skill level, Wenzlaff and Wegner (2000) had suggested other potentially testable moderators, such as the desire for suppression (which is very similar to the point of suppressive coping style discussed previously), age, and hypnotizability.

The finding that women's performance did not exhibit the same susceptibility to manipulations of mental load and attention allocation as men is interesting. The observed effect size is roughly medium in magnitude (i.e., pre-post Cohen's $d = .47$), and potentially meaningful from a population perspective. However, the cause of such a difference was unclear from the analysis because neither attention allocation nor mental load level were found to be part of the interaction. In addition, no gender difference was found on performance of baseline block. Given these results, the view that young girls and adult women exceed their male counterparts in tasks of fine manual dexterity (Nicholson & Kimura, 1996; Tiffin & Asher, 1948) was partially supported because such a superiority of women over men was shown only under manipulations of attention allocation and mental load. Furthermore, Bjorklund and Kipp (1996)'s view that women are better than men in some suppression tasks (e.g., selective attention and motor inhibition/impulse control) was not supported in the current task design because women showed better performance than did men regardless of attention allocation. From a probabilistic perspective, however, it is hard to argue that our finding is simply due to chance when the p value is $< .004$. Some underlying factors leading to such a gender difference may fail to be revealed in our study. It is therefore recommended that future investigations should pay more attention to gender difference and further test our result in similarly designed experiment, especially when the task requires manual dexterity.

Pressure and Pressure Perception Measurement

The present study obtained both SCL reading and self-report of pressure level from participants. Whereas pressure ratings plays the role of manipulation check for mental load, SCL readings was incorporated to further examine its validity in measuring pressure perception in an objective way. However, unlike pressure ratings, no significant phase by mental load interaction was identified for SCL readings. It seems that SCL readings are not sensitive to the change of perceived pressure level for the following reasons. First,

a relatively low activation level may be preferable in order to achieve hand steadiness during task accomplishment, and hence participants may purposefully contain themselves to get a better score. Considering the evidence that shooters lower their SCL in their performance (Caterini et al., 1995; Tremayne & Barry, 2001), the repressed SCL level does not necessarily imply anything about an individual's pressure perception. Moreover, it has been argued that SCL has a 2-s latency of electrodermal activity (Tremayne & Barry, 2001). Because participants receiving high mental load manipulation completed their task with a mean of about 5.4 s, this latency may well mask certain amount of effects. In short, SCL is not a reliable indicator of an individual's perceived pressure level in the present study.

In the future, researchers must pay attention when choosing biofeedback indicators. For example, the same biofeedback indicator can measure different constructs conditioning on muscular activity intensity (Salazar et al., 1990; Tremayne & Barry, 2001). More specifically, for sports involving minor physical demands (e.g., marksmanship, golf putting, sprint start), heart rate is treated as an indicator of vigilance (i.e., attentive state with focus on external stimulus events) and SCL activation-arousal level. However, in more physically demanding tasks (e.g., distance running), the cognitive effect on heart rate and SCL could be overridden by physiological factors and thus they would become indicators of other constructs.

Limitations

There are several limitations in the present research. First, the study did not measure the SCL and pressure ratings during the participants' rest period (i.e., pretest, rest interval between blocks, and posttest). These measurements could offer a new perspective on making comparisons of pressure level, and hence make the interpretation more informative. Second, this study might have been negatively affected by postsuppression rebound effect, a phenomenon that suppression of certain thoughts would enhance the following expression on that target (Wegner, Schneider, Carter, & White, 1987). Thus, participants required to rehearse and focus on "Don't shake" in the first trial block could experience certain kind of enhancement on the shake thought later. If the 5-min rest period was not long enough, such a rebound effect could spread into their second block of trial task. Yet, the learning effect would not be experimentally controlled if all the participants were instructed to perform their baseline measure in the first block, which could eliminate such a concern. Last, guidance of the ironic processing theory (Wegner, 1994) may also have limitations for integrating the whole picture of choking under pressure.

Conclusions

In the present study, Wegner's (1994) IPT was supported in an upper limb motion steadiness task for being adequate to predict one source of choking, especially when the mental

load was low. Under conditions of high mental load, however, the prediction of the theory was not well supported. Moreover, women seemed to be steadier in performing the task under different experimental conditions than did men. Finally, SCL was not a reliable measure of pressure perception.

NOTES

1. The descriptive statistics can be obtained by contacting Sicong Liu.

2. The minimum value of the y-coordinate in Figures 2–5 was chosen according to the measurement minimum of apparatus.

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Received May 7, 2014

Revised September 15, 2014

Accepted October 10, 2014