The Influence of Task Complexity on Performance and Arousal: Does the Yerkes-Dodson Law Hold True?

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Abstract

The effects of task difficulty and task type on physiological arousal levels and task performance were examined by testing participants' physiological arousal levels on a physiograph machine and scoring how well they performed on given tasks. Participants were given simple, medium, and complex tasks in either a quantitative or verbal condition, for which questions were chosen from the GRE. Three 3x2 mixed design analyses of variance were conducted to test significance between task difficulty and physiological arousal levels, task difficulty and type of task on performance scores, and type of task and physiological arousal levels. Significance was found in the main effects of task difficulty on physiological arousal levels, task difficulty on performance scores, type of task on performance scores, and the interaction of type of task and task difficulty on performance scores. There was no significant correlation found between physiological arousal levels and performance scores.

Keywords: Yerkes-Dodson Law, physiological arousal, performance, task type, task difficulty

The Influence of Task Complexity on Performance and Arousal: Does the Yerkes-Dodson Law Hold True?

The relationship between performance and physiological arousal has been one of considerable interest to researchers for numerous years (Anderson, 1994; Oxendine, 1970). The idea that physiological arousal levels may be related to performance has sparked interest in the psychological field, and many studies have been conducted that examine the interaction between these two variables (Bergstrom, 1967; McNulty & Noseworthy, 1966; Movahedi, Sheikh, Bagherzadeh, Hemayattalab & Ashayeri, 2007). Additional factors have also been added into these experiments such as task complexity, reaction time, social support, and age (Riediger, Wrzus, Klipker, Müller, Schmiedek & Wagner, 2014). The idea that there may be a pattern to the way in which arousal and performance are related was first discovered by Yerkes and Dodson (1908).

The Yerkes-Dodson Law is the foundation of which the general relationship between performance and arousal can be described (Yerkes & Dodson, 1908). This law states that performance and arousal have a positive relationship as both levels increase up until an optimal point (Yerkes & Dodson, 1908). After they reach this optimal point, the two begin to have a negative relationship as arousal levels continue to increase and performance levels then decrease (Yerkes & Dodson, 1908). One major point of this law describes the effect that situation difficulty plays; different tasks may require various arousal levels, depending on the difficulty of the task, in order to reach the optimal performance point.

The evidence behind this law is originally based on a study conducted in 1908 by Yerkes and Dodson, who tested how quickly habits could be formed in relation to different stimuli strengths. They tested the habit-formation tendencies of mice by having them choose between two different boxes to enter, either white or black, and requiring that they choose the white box (Yerkes & Dodson, 1908). To make this task more difficult, they altered the brightness of the boxes so that the mice had to discriminate between the two. If they chose to enter the black box they were given an electric shock, with the intent of determining whether this shock would influence how quickly the mice acquired the habit of going to the white box and, if so, how much of a shock would be necessary to create this habit (Yerkes & Dodson, 1908). What they discovered through this experiment was that the relationship between the strength of the electrical shock and the rapidity of habit-formation of the mice was dependent upon the difficulty of the habit (Yerkes & Dodson, 1908). This result was generally broadened to the idea that in an easy learning task there is a positive relationship between task strength and learning rapidity up until an optimal point, and then that relationship becomes inverse as tasks become increasingly more complex (Bäumler, 1994). This relationship is now known as the Yerkes-Dodson Law and has been used in a variety of situations ever since, such as looking at the interaction between arousal, different forms of arousal, and performance.

One example of varying performance situations is the influence of social facilitation (Burton & Linn, 1994). Social facilitation is the tendency for people to perform differently in the presence of others, specifically, performing better on simple or well-learned tasks and worse on complex or new tasks (Myers & Twenge, 2016). As an illustration of this tendency, Villegas (2001) looked at the power of social support to block social facilitation effects, with specific interest on the behaviors that impact performance of a complex task. The variables of this study included task complexity, social support, and performance evaluation of the subjects (Villegas, 2001). Subjects were given a memory recall task and then asked to answer a post-test questionnaire. The results of this study found that there were main effects for both task complexity and social support, meaning that participants who received support and were evaluated on complex task performance recalled more words than other participants (Villegas, 2001). Additionally, participants who felt higher levels of stress, or a state of arousal, performed better when they felt as though they were being given support (Villegas, 2001). According to the variance in the results, Villegas (2001) concluded that performance tasks under certain conditions can either be hindered or promoted by the difficulty of the task that is being performed. This is relevant to the Yerkes-Dodson Law in that performance on the tasks varied depending upon the difficulty of the task as well as stress level of the participant, which is directly related to the idea that task difficulty is a factor in the relationship between performance and arousal (Yerkes & Dodson, 1908).

Another study that looked at performance levels, conducted by Fastré, van der Klink, and van Merriënboer (2010), investigated the effect that performance-based versus competence-based assessment criteria had on task performance and self-assessment skills. Performance-based group participants were provided with a list of assessment criteria that described what students should do for the task at hand, while competence-based group participants were provided with a list of criteria describing what students should be able to do (Fastré et al., 2010). The performance-based group outperformed the competence-based group on task performance, and additionally, the higher performance of the performance-based group was reportedly reached with lower mental effort (Fastré et al., 2010). The Yerkes-Dodson Law (Yerkes & Dodson, 1908) is evident in that the performance-based groups reportedly scored higher with lower arousal when compared to competence-based groups, which represents the correlational relationship evident between performance and arousal.

Just as Fastré et al. (2010) examined performance, a study conducted by Harris and Cumming (2003) investigated the association that state and trait anxiety had with performance on prospective, retrospective, and working memory tasks. In this study, state anxiety was classified as anxiety experienced at a specific point in time that was determined by both trait anxiety and a certain situational threat, while trait anxiety was defined as a person's characteristic that implied naturally high levels of physiological arousal (Harris & Cumming, 2003). Prospective memory tasks were defined as the component of remembering to remember, while retrospective memory tasks were an attempt to remember specific content (Harris & Cumming, 2003). The working memory task came into play when subjects were given a list of ten words that they were allowed to study at a rate of one word every ten seconds, which they were later tested on (Harris & Cumming, 2003). Harris and Cumming (2003) discovered that a higher level of state anxiety was associated with decreased performance in prospective but not retrospective memory tasks, and that trait anxiety was not related to either. Thus, their results showed that an increased level of state anxiety is related to a decreased level of performance; this supports the Yerkes-Dodson Law (Yerkes & Dodson, 1908) because an increased level in arousal due to situational factors, in this case task difficulty, was also correlated with a decreased level in performance.

One factor that can affect arousal changes through task complexity is age, as demonstrated through an experiment by Riediger et al. (2014). This study compared participants of different age ranges in how they reacted to arousal, as well as how it affected their performances on working memory tasks (Riediger et al., 2014). The experiment included participants wearing a monitoring system that recorded their cardiac and physical activity. The participants were tested on their arousal condition which was either energetic arousal, defined as feeling very awake, or tense arousal, defined as feeling very nervous. The results of this study indicated that middle-aged adults that were under tense arousal, or very high physiological arousal, had significant impairment to their working memory when performing a task compared to younger participants. Thus, this study showed that cognitive performance on certain tasks appears to become more impaired as individuals get older, but does not show significant signs of impairing cognitive function of younger-aged individuals (Riediger et al., 2014). This is relevant to the Yerkes-Dodson Law (1908) because it shows that individuals' optimal arousal levels differ with age.

A comparative study testing performance levels was reported by Bergstrom (1967), in which he found that experienced pilots performed poorer on a complex motor task during stressful conditions, consisting of distracting flashing lights and the ability to also perform a secondary task as well (Bergstrom, 1967). He stated that pilots can normally perform difficult and complex tasks in a calm lab situation, or a mock cockpit simulation, however, when they are airborne their performance deteriorates as a result of their high stress levels (Bergstrom, 1967). Thus, this study seems to support the findings that certain tasks are hindered by high levels of arousal or stress, as the complex task in the highly stressful condition elicited a poorer performance by the pilots than the complex task during a mock simulation. This outcome is what Yerkes and Dodson (1908) would have expected, as the complex task required an increased level of concentration that could not be obtained due to the high levels of arousal and stress.

Movahedi et al. (2007) also studied the relationship between performance and arousal in an experiment in which they assigned male participants to either high arousal or low arousal groups to test them on peak performance levels in a motor task. Participants' arousal was manipulated using various motivational techniques, and their arousal levels were measured by heart rate (Movahedi et al., 2007). At the determined arousal state, the two groups performed a task of shooting basketball free throws, and then ten days later were tested on their task retention (Movahedi et al., 2007). The results showed that both groups learned the free throw task in a similar manner and achieved peak performance at the experienced arousal level, but when they were tested at an arousal level different than the one they had practiced in, their performance significantly deteriorated (Movahedi et al., 2007). These findings suggest that performance had become integrated with arousal level during task learning, meaning that the participant had learned the skill as well as how to perform that skill in their assigned arousal condition. This suggests a practice-specific based explanation for peak performance, meaning that participants perform better at a certain arousal level if they have also practiced at that arousal level (Movahedi et al., 2007). This is important to the Yerkes-Dodson Law (Yerkes & Dodson, 1908) because it indicates that an individual will have an optimal performance point based on the arousal condition that they practiced and performed in.

Continuing to study the relationship between arousal and performance, McNulty and Noseworthy (1966) studied two different groups using various learning tasks such as verbal and motor. One of the groups performed these tasks under a high arousal level, defined as being given an electric shock, and the other group performed the tasks under a low arousal level, which was defined as no electric shock (McNulty & Noseworthy, 1966). The participants' physiological measures were also recorded in a variety of other ways including muscle tension, heart rate, blood pressure, etc. (McNulty & Noseworthy, 1966). The results showed that arousal did not affect subjects' performances on verbal tasks, however, in the motor tasks they found that performance was generally better under high arousal conditions rather than low arousal conditions (McNulty & Noseworthy 1966). Additionally, they found that the participants' performance also varied depending upon their physiological measurements, meaning that the way participants channel their arousal could have influenced their performance (McNulty & Noseworthy, 1966). Thus, McNulty and Noseworthy (1966) found that arousal only has an impact on certain tasks under certain conditions, this case being motor tasks under high arousal levels. This is important to the Yerkes-Dodson Law (Yerkes & Dodson, 1908) because it represents how arousal can impact performance based on the type and difficulty of the task.

To demonstrate the Yerkes-Dodson Law in a different situation, VaezMousavi, Barry, Rushby, and Clarke (2007) studied task performance and activation, defined as the task-related change in state from a person's normal baseline to the task situation, by recording reflex time and subjects' levels of electrodermal activity (VaezMousavi et al., 2007). The experimenters studied an across-subjects examination of arousal, which is the energetic state of a person at any particular time, and activation to examine the effects these factors have on physiological and behavioral responses during a continuous performance task (VaezMousavi et al., 2007). Participants were given a number cue and asked to respond by hitting a button within a certain time frame. The results found that the reflex of the participants was mainly dependent on arousal rather than activation, however, reaction time improved with increasing relative activation (VaezMousavi et al., 2007). Thus, VaezMousavi et al. (2007) concluded that different aspects of the individual's state determine physiological and behavioral responses to stimuli. This study indicates that arousal does have an effect on individuals' performance, in this case reflex time, because participants' reflexes changed as their arousal levels changed. This change in performance in relation to change in arousal relates back to the Yerkes-Dodson Law (Yerkes & Dodson, 1908).

In looking at how the Yerkes-Dodson Law holds true when changing the task difficulty of subjects, Denenberg and Karas (1960) discovered that arousal levels decrease over repeated experiences of a performance task. They demonstrated this by testing mice on solving a maze, in which the mice were to continue repeating the maze for five trials (Denenberg & Karas, 1960). On the sixth trial, the mice were given a less challenging task that lowered their arousal levels because it was simpler. The results of this study showed that the difficult task was more arousing and had lower performance rates, while the simpler task was less arousing and had higher performance rates (Denenberg & Karas, 1960). This study indicated results that are similar to Yerkes and Dodson (1908), in that arousal and performance seem to be negatively correlated. While Denenberg and Karas conducted their experiment on mice, their results closely mirror those of the previously described studies conducted on humans (Harris & Cumming, 2003;VaezMousavi et al., 2007).

Furthermore, a study conducted by Oxendine (1970) depicted that high levels of arousal are essential for optimal performance of gross motor activities involving strength, endurance, and speed. However, a high level of arousal interferes with complex skills, coordination, or fine muscle movements, so a slightly above average level of arousal is considered preferable (Oxendine, 1970). It has been found that different tasks require different levels of arousal for an individual's most effective performance, and that levels of arousal and physical performance at various levels are reported (Oxendine, 1970). In tasks of low difficulty, high anxious subjects were found to be superior, while in tasks of high difficulty, low anxious subjects proved superior (Oxendine, 1970). This study, like Movahedi et al. (2007), relates to the optimal point of arousal and performance of the Yerkes-Dodson Law, which states that a participant who is highly anxious or aroused would perform better on the lower complexity task because the more complex task would induce an even higher state of anxiety. The low anxious participants would perform better on the more complex task because as task complexity goes up, so do participants' arousal levels, but only until the optimal point is reached (Yerkes & Dodson, 1908).

In a study most similar to the present one, Anderson (1994) performed a within-subjects study in which each participant's arousal level was manipulated by being given five different doses of caffeine. Participants had to perform both an easy and complex task for each dose of caffeine that they consumed (Anderson, 1994). They were then asked to perform a simple task, a letter cancellation task where they were required to cross out certain letters, and a complex task, for which they had to use their verbal abilities. The results indicated that as caffeine levels increased, so did participants' performance on the simple task (Anderson, 1994). Contrarily, on the complex task, an inverse relationship occurred between increased caffeine levels and decreased performance (Anderson, 1994). Thus again, the results are consistent with that of the Yerkes-Dodson Law (1908) because it indicates that task difficulty impacts participants' performance and arousal levels.

While each of these studies discuss various tasks that lead to an increase in arousal levels, it is also important to look at how arousal levels can be lowered. There are numerous studies conducted on meditation's effects on physiological arousal (Cauthen & Prymak, 1977; Cuthbert, Kristeller, Simons, Hodes, & Lang, 1981; Holmes, 1984). Cuthbert et al. (1981) examined the effectiveness of meditative exercises on lowering participant's arousal and activation levels. They found that even when participants were trained in heart rate slowing, intended to decrease heart rate, activation, and arousal levels, meditation was superior in lowering arousal (Cuthbert et al., 1981). Another study looking at mediation and arousal by Cauthen and Prymak (1977) tested groups trained in either relaxation or meditation for heart rate and skin conductance. They discovered that the groups consisting of experienced meditators showed decreases in heart rate during meditation, while the relaxation group did not (Cauthen & Prymak, 1977). Thus, these studies indicate that meditation has some influence on lowering individuals' arousal levels to some degree.

Each of the previously cited studies depict, at the very least, some form of relationship between performance and physiological arousal levels. Using information acquired from each of these experiments, the present study aimed to look further into the effect of task complexity on participant performance and arousal levels, which was measured on a physiograph machine using skin conductance data. Specifically, this study used simple, medium, and complex versions of both a verbal and quantitative task in order to test whether this affected the participants' arousal levels and, consequently, their performance scores. It was hypothesized that participants in the simple condition would have a low level of arousal and obtain a higher performance score, participants in the medium condition would reach the optimal level of both performance and arousal, and participants in the complex condition would continue to have increased arousal levels while their performance score decreased.

Method

Participants

Approximately 66 Ripon College students participated in this study, 33 per condition, ranging from 18 to 33 years old with a mean age of 19.76. There were 27 participants that identified as male, and 39 participants that identified as female. Students from various psychology courses, as well as the general student body, were recruited to participate. In some cases, participants from psychology courses were given extra credit for participation. All participants were tested in accordance with the "Ethical Principle of Psychologists and Code of Conduct" (American Psychological Association, 2002).

Materials

Participants were tested in room B18 in the basement of Todd Wehr. An HRM Biofeedback MicroLab version 1.5 was used to collect skin conductance data through an Apple IIe microcomputer, along with silver chloride electrodes and Signa Gel. Participants were randomly assigned to either the verbal or quantitative condition and given three tasks of varying difficulty: simple, medium, and complex (see Appendices A through F). All participants were given a pen and additional sheets of paper to record their work, while those who were assigned to the quantitative condition were also allowed a calculator. All participants were shown a 60 second meditation video (YellowBrickCinema, 2015) with the intent of lowering their physiological arousal levels in between tasks.

Procedure

Before participants arrived, they were randomly assigned to complete either the verbal or quantitative task, of which nine questions were taken from the Kaplan Graduate Record

Examination textbook (Ahn, Alexeef, Allison, Matthew, Bowers, Carlidge, & Weiss, 2016), and were again randomly assigned to the order in which they completed the simple, medium, and complex tasks. Before beginning the study, the experimenters gave each participant a consent form. Upon signing the consent form, the participant was hooked up to the Biofeedback apparatus by applying a small amount of electrode gel and two silver chloride electrodes attached to the palmar side of the first and third fingers of the non-dominant hand.

The experimenters instructed participants that they would be given three different tasks, each of which had three questions. They were to read the first question, decide upon the correct answer, and then say their answer out loud. Once they answered the question, they were then prompted by the experimenter to move on to the next question in which the same procedure occurred, and this was repeated until all questions for that task were answered. Participants assigned to the verbal condition were given 45 seconds to complete each question, while participants in the quantitative condition were given 105 seconds to complete each question. These time limits were determined based on a pilot study conducted on students in the psychology research seminar class. After the participants completed a task they were shown a meditation video (YellowBrickCinema, 2015), lasting approximately 60 seconds, with the intent of lowering their physiological arousal level between tasks. The participants then continued on with the next task, for which the same procedure occurred and video was shown, until they had completed all three tasks. At this point, the experimenters removed the electrodes and debriefed participants on the purpose of the study.

Scoring

Participants' performance on the simple, medium, and complex tasks, in both the verbal and quantitative condition, were scored based upon the number of correct answers they gave out of the nine questions. Physiological arousal was recorded in microsiemens at two-second intervals throughout the session. A marker was placed in the record each time the participant answered a question. Responses were then averaged for the six seconds before each answer (A), and for the six seconds following each answer (B). A was then subtracted from B to get a value for each response. With this method, results in positive numbers indicated an increase in skin conductance, which signified an increase in physiological arousal. Because the range of responses varied considerably across participants, each participant's nine responses - three in the simple task, three in the medium task, three in the complex task - had to be transformed into z-scores for easy comparison across participants. The responses in each condition were then averaged for each participant, leaving one arousal score per condition per participant. Since the order in which participants took the tasks was randomized, the arousal scores were then organized by condition and placed into SPSS to be used for the statistical analysis.

Results

Three 3x2 mixed design analyses of variance (ANOVA) were conducted of within-subjects factors of task difficulty (simple vs. medium vs. complex) and between-subjects factors of task type (verbal vs. quantitative). The first ANOVA examined participants' physiological arousal levels, the second ANOVA looked at participants' performance scores, and the third ANOVA used participants' raw physiological levels to identify differences between task type. A Pearson correlation between performance score and arousal level was also conducted to identify if there was a significant relationship between the two factors in each condition of task difficulty.

The first ANOVA analyzed task difficulty and participants' physiological arousal levels (See *Figure 1*). The main effect of task difficulty was found to be significant on participants' arousal levels, $F(2, 64) = 4.407$, $p = .014$, $\eta^2_p = .064$, with an observed power of .751. A Bonferroni pairwise comparison was then conducted to identify which task difficulty conditions were significant from one another. Participants had significantly higher arousal levels, $p = .028$, when performing on the complex task, ($M = .182$, $SD = .495$) versus the simple task, ($M = -.100$, $SD = .492$). Participants' also had significantly higher arousal levels, $p = .049$, on the complex task versus the medium task, ($M = -.082$, $SD = .501$). There was no significance found in arousal levels between the simple task and the medium task, $p = 1.00$.

The second ANOVA compared the performance scores of the participants. The ANOVA illustrated that there was a significant main effect of task difficulty on participants' performance scores, $F(2, 64) = 99.908$, $p = .000$, $\eta^2_p = .610$, and an observed power of 1.000. Bonferroni pairwise comparisons were then administered to further examine the significance between task difficulty conditions. It was discovered that participants performed significantly better, $p = .000$, on the simple task, ($M = 2.030$, $SD = 1.067$) than on the medium task, ($M = 1.258$, $SD = .730$). Participants also performed significantly better, $p = .000$, on the simple task than the complex task, ($M = .379$, $SD = .548$). Furthermore, performance scores were higher on the medium task than on the complex task, $p = .000$. The main effect of task type was also found to be significant on participants' performance scores, $F(1, 64) = 23.664$, $p = .000$, $\eta^2_p = .270$. The observed power was .998. This means that participants' performance was significantly superior in the verbal condition, (*M* = 1.444, *SD* = .594), than in the quantitative condition, (*M* = 1.000, *SD* = .677). The ANOVA also displayed a significant interaction occurring between task type and task difficulty for participants' performance scores, $F(2, 64) = 37.833$, $p = .000$, $\eta^2_p = .372$. The observed power was 1.000.

To further explore this significance, a simple effects using a Bonferroni correction was run to compare the interaction of task type and task difficulty (See *Figure 2*). In the quantitative condition, participants were found to have significantly higher performance scores, *p* = .000, on the simple task, (*M* = 1.242, *SD* = .936), than on the complex task, (*M* = .303, *SD* = .529). Participants also performed significantly better on the medium task, (*M* = 1.455, *SD* = .564) than on the complex task in the quantitative condition, *p* = .000. However, there was no significance found between the simple and medium task, *p* = .836. In the verbal condition, participants performed significantly better, *p* = .000, on the simple task, (*M* = 2.818, *SD* = .392), than on the medium task, (*M* = 1.061, *SD* =.8269), and significantly better on the simple task than the complex task, (*M* = .455, *SD* = .5641), *p* = .000. Participants also performed significantly better on the medium task in comparison to the complex task, *p* = .000.

The third ANOVA inspected the difference in means of task type in each task difficulty condition using the raw data of participants' physiological arousal levels (See *Figure 3*). There were no significant differences found between the verbal and quantitative task in each of the difficulty conditions (see *Table 1*). A Pearson correlation was also conducted to examine if there was a significant relationship between participants' physiological arousal levels and performance scores for each of the task difficulty conditions. Again, there was no significant relationship between the two variables (see *Table 2*).

Discussion

It was hypothesized that task difficulty would have an impact on both the participants' arousal levels as well as their performance scores. Specifically, participants' arousal would be low in the simple condition with a higher performance score, they would reach an optimal level of arousal and performance score in the medium condition, and their arousal would continue to increase while performance decreased in the complex condition. The physiological arousal hypotheses were partially supported, in that this study found that participants had significantly higher arousal during the complex task versus the medium and simple tasks. However, participants did not have significantly higher arousal in the medium task versus the simple task as the means were very close to one another, thus, this part of the hypothesis was not supported. The performance hypotheses were also partially supported, in that participants performed significantly better in the simple task versus the medium and complex tasks, and performed significantly better in the medium task versus the complex task. This means that the mean score of participants was high in the simple task, average in the medium task, and low in the complex task. However, this only partially supported the hypothesis because the experimenters believed that the medium task would be conducive to participants' optimal level of performance, whereas performance levels were actually lower during the medium task than during the simple task.

While there were no predictions hypothesized regarding a difference in participants' performance in task type, there was significance found between performance scores in the verbal task compared to the quantitative task. Participants performed significantly higher in the simple condition than the medium or complex conditions on the verbal task, as well as significantly higher in the medium condition versus the complex condition. This means that participants given the verbal task performed better in the simple condition than all other conditions. In the quantitative task, participants performed significantly higher in the simple condition versus the complex condition, and significantly higher in the medium condition versus the complex condition. However, there were no significant performance differences between the simple and medium conditions for those who were given the quantitative task. This means that participants given the quantitative task performed more poorly in the complex condition compared to the simple and medium conditions, but there was no significance between the simple and medium conditions. These results are related to that of McNulty and Noseworthy (1966) who altered participants' arousal levels and found that this had an impact on performance on motor tasks in the high arousal level. This is not identical to the present study considering that McNulty and Noseworthy (1966) used an external stimulus, in the form of an electric shock, to increase arousal levels. However, it does indicate that there is a relationship between task type, difficulty, and performance levels. Their study also demonstrated that arousal has an impact on certain tasks under certain conditions, which is evident in the present study as well (McNulty & Noseworthy, 1966).

The results of participants' performance and arousal levels in the present study were also somewhat consistent with the results of Anderson (1994), who found that task difficulty and arousal had an impact on performance. His study was similar to the current study in that participants had increased arousal levels and decreased performance scores in the complex condition. Contrastingly, his study differed in that he manipulated participants' arousal levels by providing doses of caffeine, thus, he was able to find participants' optimal level of arousal. The current study did not manipulate arousal levels and instead used participants natural skin conductance to measure arousal, and so was not able to find participants' optimal arousal levels. However, while there are differences between the studies, both represent that there is a relationship between task difficulty, performance, and arousal. The study by Oxendine (1970) also indicates that there is a relationship between task complexity and optimal arousal levels. He depicted that in highly difficult tasks, participants with lower levels of arousal performed better because complex tasks induce a higher state of anxiety, thus, those with high arousal would only become more anxious (Oxendine, 1970). The present study supported this hypothesis since participants had decreased performance scores and high arousal levels in the complex task. However, again, this study was not able to locate the optimal point for arousal and performance while Oxendine (1970) was able to do so.

There were multiple limitations within this study that could have prevented full support of the hypotheses. The first is the small sample size of participants in the study. Only 66 participants participated in the study, and a total of 124 participants were recommended to achieve the necessary power with a medium effect size of .06. Another limitation was that the meditation video may not have been the most accurate way to lower participants' arousal levels in between tasks. There are a few reasons for this, the first being that the meditation video was only shown to participants for 60 seconds in between tasks, thus, this may not have been long enough to lower their arousal levels. Another reason may be that the video was simply not effective, either because it was not enough to relax participants or because participants were thinking of other things rather than focusing on the video. This relates to participants' motivation levels, which may be a contributing factor to their performance specifically in the quantitative condition. It was clear that some participants did not want to put the necessary amount of effort in to achieve the correct answer, thus, they may have ended up simply guessing on the answers.

Additionally, the quantitative and verbal tasks that were used may not have been comparable to each other across the difficulty conditions. The quantitative condition seemed to be much more difficult for participants compared to the verbal condition, and this could have affected their performance and arousal. One of the main limitations of this study was that there was no accurate way to measure participants' optimal arousal level. Since participants' arousal levels were not manipulated, and each participant has a different arousal baseline, it was difficult to predict what each person's optimal point would be. Thus, there was no accurate measure or prediction of this and so it was not evident in the results of the study.

In the future, there are different approaches that could be used to test the Yerkes-Dodson Law. One manipulation could be including the use of physical tasks, such as shooting a basketball as Movahedi et al. (2007) tested, to see how this may affect participants' arousal levels and performance. A variety of mental tasks may also be interesting to study; this experiment used GRE questions since it was a relevant task for the population involved, but others, including a reading task, crossword puzzle, LSAT questions, or ACT questions, may also be interesting to look at as other studies have indicated that there are various influences on arousal levels in participants (e.g., McNulty & Noseworthy, 1966). Finding different ways to manipulate participants' arousal levels such as measuring heart rate, exposing participants to an electric shock, or administering caffeine to participants, is another variation that could be further explored (e.g., Anderson, 1994; McNulty & Noseworthy, 1966). Studying the differences in arousal levels and performance scores between genders and ages may be another direction that future research could head towards. As Riediger et al. (2014) indicated, age may be a factor in arousal level, thus, it would be an interesting one to explore. However, using age as a factor may be difficult because it would require finding a task that is equivalent across people of all ages. It would also be interesting to see if participants' majors had an effect on arousal levels and performance scores; for example, comparing results of math majors on the quantitative portion to those who have majors with little math experience.

As discussed, there are endless opportunities to further explore the Yerkes-Dodson Law. The findings in this study are important because they can be applied to real-life situations, such as students' experiences in school. For example, taking a difficult test could influence a change in a student's arousal levels, which could have an effect on how well they perform on the test. If the test is distressing to the student, their arousal levels may be high and evoke lower performance scores; however, if the student is well-prepared, they may have lower arousal as well as higher performance. This study shows that more research needs to be conducted on ways to lower individuals' arousal levels, because even though there is research indicating that meditation can lower arousal (Cauthen & Prymak, 1977; Cuthbert et al., 1981), it is not always consistent in doing so. The experimenters believe that research on lowering arousal is important because the present study and previous studies (McNulty & Noseworthy, 1966; Movahedi et al., 2007; Oxendine, 1970) demonstrate that arousal levels can influence performance scores; thus, if individuals could practice ways to lower their arousal, they may be able to obtain higher performance in school, athletic, or job situations.

Overall, the findings of this study support aspects of the Yerkes-Dodson Law and indicate that there is a relationship between task difficulty, performance, and arousal. This relationship is important because it helps to understand how changing task difficulty can affect an individual's arousal level and performance ability, which can be applied to various situations. Thus, with further research on the Yerkes-Dodson Law, there is the possibility of deeper knowledge and understanding of this theory's real-world application.

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Table 1

Raw Physiological Arousal Level Means

	Verbal			Quantitative		
	Simple	Medium	Complex	Simple	Medium	Complex
Mean	.127	.166	.290	.406	.273	.306
Std Dev.	.248	.245	.438	.846	.354	.356

Note. Means of the raw physiological arousal levels of participants in the simple, medium, and complex tasks in the quantitative and verbal conditions. None of these reported values are significant.

Table 2

Pearson Correlation of Arousal and Performance

	Simple Performance	Medium Performance	Complex Performance
Simple Arousal	.716	.605	.182
Medium Arousal	.351	.902	.928
Complex Arousal	.562	.697	.218

Note 2. Pearson correlation illustrating participants' physiological arousal levels compared to performance scores of the participants. Significance depends on the p value: Significant at the $p < 0.05$ level. There was no significance found.

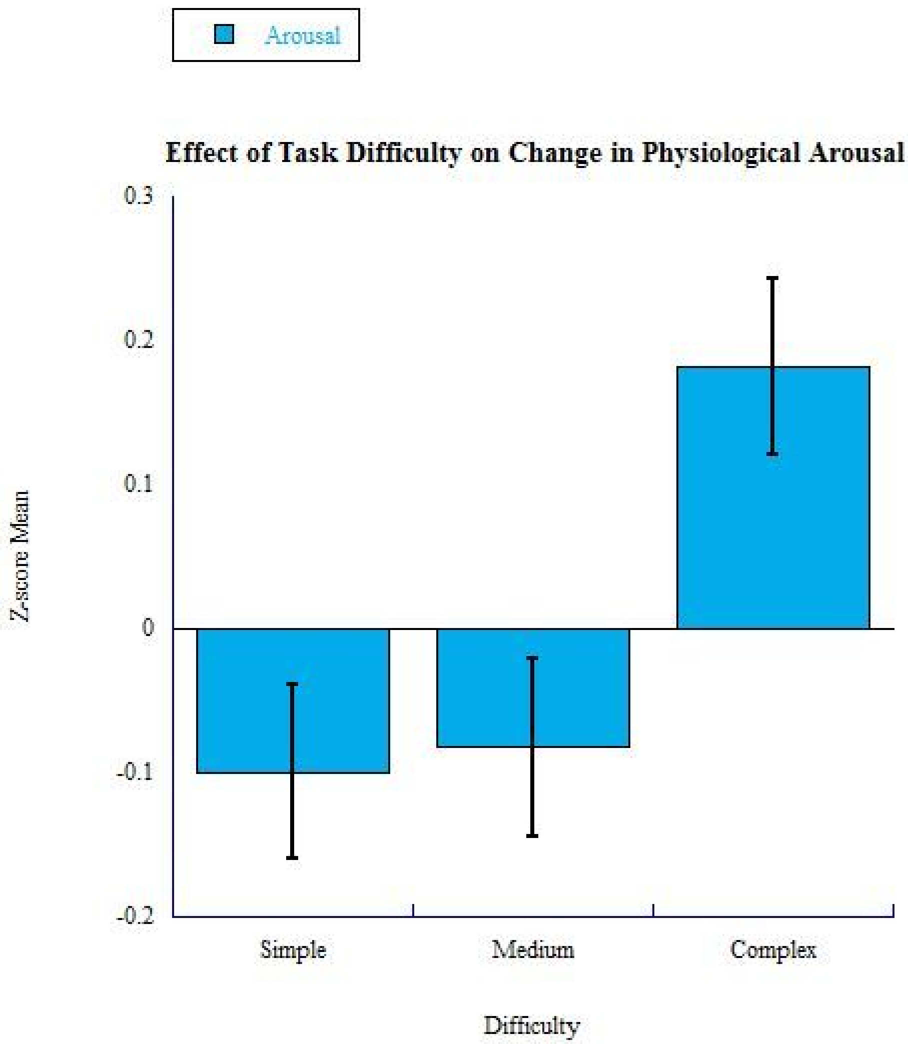

Figure 1. Mean z-scores representing change in participants' physiological arousal levels in simple, medium, and complex conditions of task difficulty. Significance between means of simple and complex conditions was found, as well as between means of medium and complex conditions. Error bars indicate standard error of the mean.

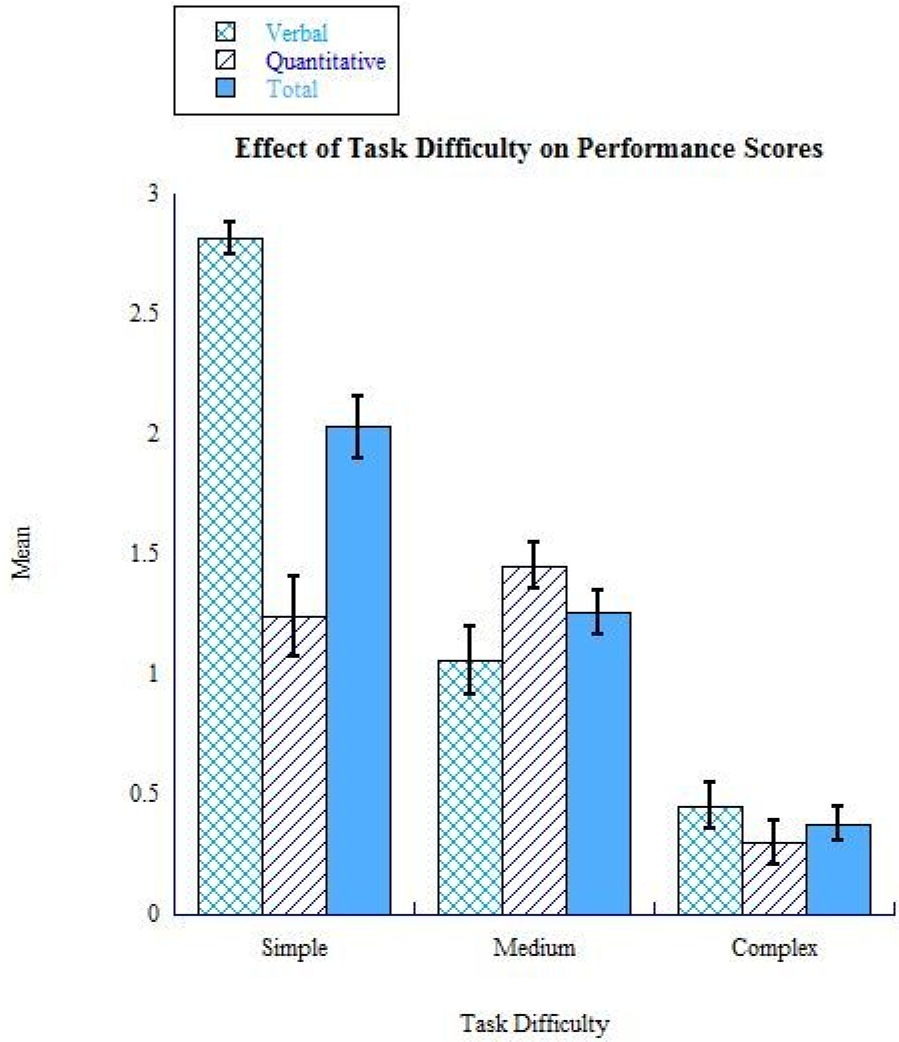

Figure 2. Means representing participants' performance scores in verbal and quantitative tasks in simple, medium, and complex conditions of task difficulty. Significance was found in the verbal task between all task difficulty conditions. Significance was also found in the quantitative task between the simple and complex conditions, as well as between the medium and complex conditions. Error bars indicate standard error of the mean.

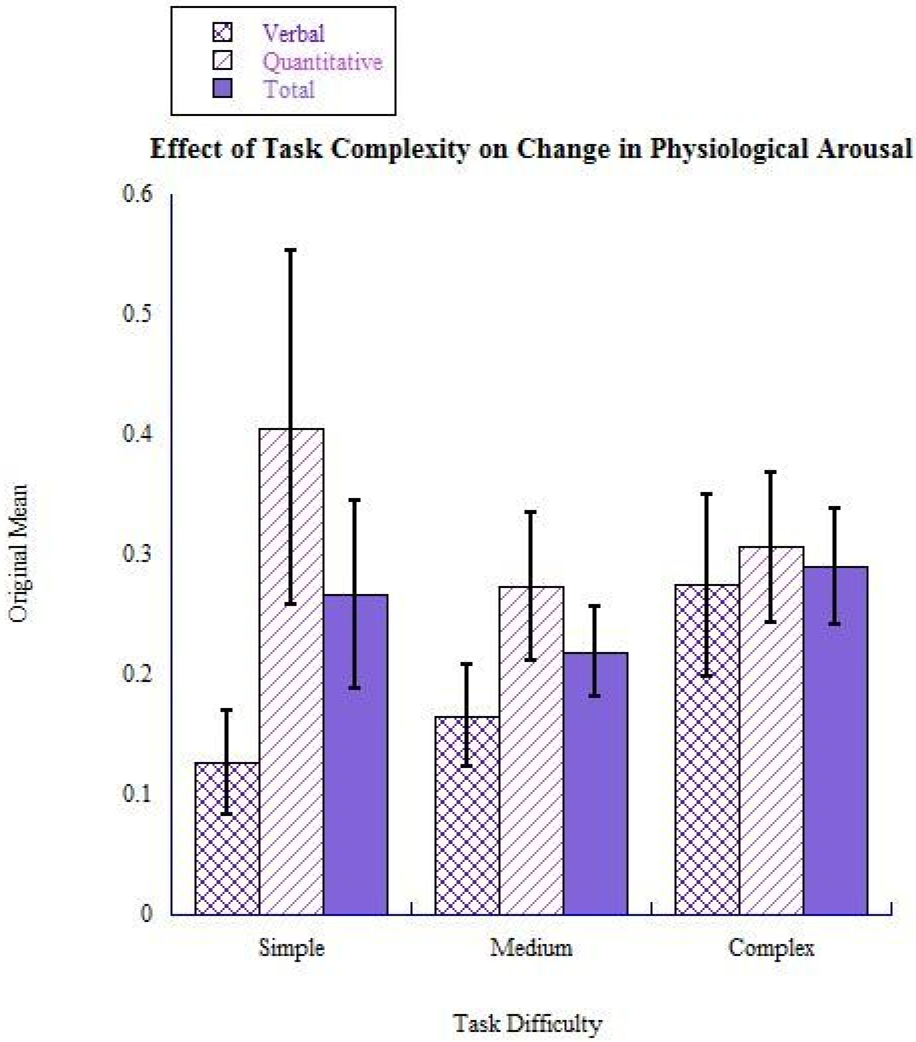

Figure 3. Means representing change in participants' physiological arousal levels, before z-score calculation, in verbal and quantitative tasks in simple, medium, and complex conditions of task difficulty. No significant differences were found between means. Error bars indicate standard errors of the mean.

Appendix A

Verbal Task: Simple

________ **1.** Ruth mistook Katrina's ______ for unfriendliness; in fact, Katrina meant nothing by not talking to Ruth.

A. Message
B. Silence
C. Contact
D. Preference
E. Illness

________ **2.** Jan dreamed of living in a better apartment, but because she did not have the money to do so, she knew that a change in residence was _________.

A. Delayed
B. Unnecessary
C. Unlikely
D. Financial
E. Captured

________ **3.** Since Porter _____ cats, he did not want to visit Flynn's house, which had three cats.

A. Petted
B. Understood
C. Disliked
D. Advanced
E. Sold

Verbal Task: Simple - Answers

________ **1.** Ruth mistook Katrina's ______ for unfriendliness; in fact, Katrina meant nothing by not talking to Ruth.

A. Message
B. **Silence**
C. Contact
D. Preference
E. Illness

________ **2.** Jan dreamed of living in a better apartment, but because she did not have the money to do so, she knew that a change in residence was _________.

A. Delayed
B. Unnecessary
C. **Unlikely**
D. Financial
E. Captured

________ **3.** Since Porter _____ cats, he did not want to visit Flynn's house, which had three cats.

A. Petted
B. Understood
C. **Disliked**
D. Advanced
E. Sold

Appendix B

Verbal Task: Medium

________ **1.** There is something lurid and _____________ about a system that subtly tempts people into criminal activities that they would never be interested in otherwise.

A. Enervating
B. Lascivious
C. Picayune
D. Insidious
E. Pervasive

________ **2.** Ryan is paralyzed by his own __________: he imagines having elaborate conversations with various people, but he fails to engage in conversations with them when opportunities arise.

A. Diffidence
B. Sycophancy
C. Imagination
D. Convalescence
E. Rectitude

________ **3.** Popular history frequently ___________ important events, but a method in which all sides are fully economically explained has yet to be found.

A. Ignores
B. Disputes
C. Exacerbates
D. Abbreviates
E. Defiles

Verbal Task: Medium - Answers

________ **1.** There is something lurid and _____________ about a system that subtly tempts people into criminal activities that they would never be interested in otherwise.

A. Enervating
B. Lascivious
C. Picayune
D. Insidious
E. Pervasive

________ **2.** Ryan is paralyzed by his own __________: he imagines having elaborate conversations with various people, but he fails to engage in conversations with them when opportunities arise.

A. Diffidence
B. Sycophancy
C. Imagination
D. Convalescence
E. Rectitude

________ **3.** Popular history frequently ___________ important events, but a method in which all sides are fully economically explained has yet to be found.

A. Ignores
B. Disputes
C. Exacerbates
D. Abbreviates
E. Defiles

Appendix C

Verbal Task: Complex

________ **1.** One business partner was parsimonious while the other was ________, but they were very successful in working together.

- **A.** Prolix
- **B.** Obstreperous
- **C.** Spendthrift
- **D.** Dictatorial
- **E.** Energetic

________ **2.** There is a prevailing attitude in this country that scientific disciplines have more legitimate methodologies than the humanities and social sciences do, but this sentiment routinely ignores the fact that so much scientific data is _______________.

- **A.** Quantum
- **B.** Unknown
- **C.** Doctored
- **D.** Irrefutable
- **E.** Irreducible

________ **3.** The town council preferred him to be modest about his exploits, and his present fits of hubris were met with resounding ____________.

- **A.** Encomium
- **B.** Perspicacity
- **C.** Obloquy
- **D.** Pastiche
- **E.** Panegyric

Verbal Task: Complex - Answers

________ **1.** One business partner was parsimonious while the other was ________, but they were very successful in working together.

A. Prolix
B. Obstreperous
C. Spendthrift
D. Dictatorial
E. Energetic

________ **2.** There is a prevailing attitude in this country that scientific disciplines have more legitimate methodologies than the humanities and social sciences do, but this sentiment routinely ignores the fact that so much scientific data is _______________.

A. Quantum
B. Unknown
C. Doctored
D. Irrefutable
E. Irreducible

________ **3.** The town council preferred him to be modest about his exploits, and his present fits of hubris were met with resounding ____________.

A. Encomium
B. Perspicacity
C. Obloquy
D. Pastiche
E. Panegyric

Appendix D

Quantitative Task: Simple

________ **1.**

Quantity A	Quantity B
75 percent of 340	340 percent of 75

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal
D. The relationship cannot be determined from the information given.

________ **2.**

$a < 0 < b$

Quantity A	Quantity B
$b - a$	A

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

.

________ **3.**

A fair 6-sided die was rolled 7 times and each time a 6 was rolled.

Quantity A	Quantity B
The probability of not rolling a 6 the next time the die is rolled	$\frac{5}{6}$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined.

Quantitative Task: Simple - Answers

_________ **1.**

Quantity A	Quantity B
75 percent of 340	340 percent of 75

A. Quantity A is greater.
B. Quantity B is greater.
C. **The two quantities are equal**
D. The relationship cannot be determined from the information given.

_________ **2.**

$a < 0 < b$

Quantity A	Quantity B
$b - a$	A

A. **Quantity A is greater.**
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

_________ **3.**

A fair 6-sided die was rolled 7 times and each time a 6 was rolled.

Quantity A	Quantity B
The probability of not rolling a 6 the next time the die is rolled	$\frac{5}{6}$

A. Quantity A is greater.
B. Quantity B is greater.
C. **The two quantities are equal.**
D. The relationship cannot be determined.

Appendix E

Quantitative Task: Medium

________ **1.** *n* is a positive integer.
One integer is chosen at random from the first *n* positive integers.

Quantity A	Quantity B
The probability that the integer chosen is even	The probability that the integer chosen is odd

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

________ **2.**

Quantity A	**Quantity B**
$\frac{6}{7}+\frac{8}{9}$	$\frac{5}{6}+\frac{7}{8}$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.
E.

________ **3.**

$xy > 0$

Quantity A	Quantity B
$\lvert x\rvert + \lvert y\rvert$	$\lvert x + y\rvert$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

Quantitative Task: Medium - Answers

________ **1.** *n* is a positive integer.
One integer is chosen at random from the first *n* positive integers.

Quantity A	Quantity B
The probability that the integer chosen is even	The probability that the integer chosen is odd

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

________ **2.**

Quantity A	**Quantity B**
$\frac{6}{7}+\frac{8}{9}$	$\frac{5}{6}+\frac{7}{8}$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

________ **3.**

$xy > 0$

Quantity A	Quantity B
$\lvert x\rvert + \lvert y\rvert$	$\lvert x+y\rvert$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

Appendix F

Quantitative Task: Complex

_________ **1.**

a, b, c, and d are integers.
$1 < a < b < c < d$
$abcd = 210$

Quantity A	Quantity B
c	5

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

_________ **2.**

$$x^2(x - 8)(x - 4)(4x - 7)(x^2 + 4)(x^2 - 36) = 0$$

Quantity A	Quantity B
The number of different possible values of x that are positive integers	3

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal
D. The relationship cannot be determined from the information given.

_________ **3.**

For all $x \neq -y$, $x{\bullet\bullet\bullet}y = \frac{x - y}{y + x}$.
$a > 0 > b$

Quantity A	Quantity B
$a{\bullet\bullet\bullet}b$	$b{\bullet\bullet\bullet}a$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

Quantitative Task: Complex - Answers

________ **1.**

a, b, c, and d are integers.
$1 < a < b < c < d$
$abcd = 210$

Quantity A	Quantity B
c	5

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

________ **2.**

$$x^2(x-8)(x-4)(4x-7)(x^2+4)(x^2-36)=0$$

Quantity A	Quantity B
The number of different possible values of x that are positive integers	3

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal
D. The relationship cannot be determined from the information given.

________ **3.**

For all $x \neq -y$, $x•••y = \frac{x-y}{y+x}$.
$a > 0 > b$

Quantity A	Quantity B
$a•••b$	$b•••a$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.