Mindfulness and Time Perception

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Abstract

Mindfulness and attention are positively correlated, as are attention and time perception. The current study examined the relationship between mindfulness and time perception in order to test the hypothesis that increased mindfulness is related to a longer and more accurate perception of time. The method used was a correlational design that included self-reported measures of mindfulness, time perception, and time affluence, as well as behavioral tasks used to measure time perception. A relationship was found between trait mindfulness and self-reported time affluence that indicated that people higher in mindfulness felt "wealthier" in time. Additionally, a positive trend was found between a time perception behavioral task and state mindfulness, suggesting that as state mindfulness increased, time perception also increased. Findings supported the hypothesis that greater mindfulness is linked with more time affluence, and partially supported the link between mindfulness and a longer perception of time, as well. However, the hypothesis that increased mindfulness is associated with a more accurate perception of time was not supported. Since time affluence has been linked to greater well-being (Kasser & Sheldon, 2009) the current study has implications for a potentially important mechanism of mindfulness towards wellbeing, i.e., time perception.

Mindfulness and Time Perception

Mindfulness can generally be defined as non-judgmental attention or awareness of the present moment, or in other words, being present-moment focused (Kabat-Zinn, 1994). Mindfulness has been linked to many positive effects – even to better physical health (Black, 2010; Gilbert & Waltz, 2010). Some of its mental health benefits include decreased stress, increased subjective well-being, increased acceptance and compassion, and increased emotion self-regulation (Brown & Ryan, 2003; Greeson, 2009; Keng, Smoski, & Robins, 2011; Shapiro, Oman, Thoresen, Plante, & Flinders, 2008). Since mindfulness involves paying attention to the present moment, it follows that an individual higher in mindfulness would perceive time in a unique way from people low in mindfulness. The relationship between mindfulness and time perception has been explored, but not to its fullest extent. The subject of this paper is whether or not increased mindfulness is related to a longer and more accurate perception of time.

Time perception is defined as one's subjective experience of time, and one's ability to estimate or reproduce a given time period is affected by this subjectivity (Kline & Reed, 2013). One may ask what happens when these two concepts are combined – do people higher in mindfulness experience a "stretching" or "lengthening" of time? Since this topic has not been previously researched directly, we will draw upon the theory and measures used in prior studies that have separately investigated these topics.

The concept of mindfulness was originally taken from Buddha's teachings, and can be cultivated with meditation (Ameli, 2014). Researchers also consider it to be a trait that varies between people. Mindfulness can be measured in two ways: trait mindfulness and state mindfulness. Trait mindfulness refers to a person's mindfulness as a relatively stable characteristic that can change over one's life, while state mindfulness refers to a person's mindfulness at the time when it is being measured (a temporary behavior). Mindfulness can be induced in people by drawing their attention to a specific component of their subjective experience. Mindfulness meditations often direct people to pay attention to their breathing or another part of their body state, or to simply focus on the present moment.

Research has established that trait mindfulness has been linked to neural pathways already established with attentional processes. One study specifically explored the neural mechanisms behind the attention processes that result from mindfulness inductions (Dickenson, Berkman, Arch, & Liberman, 2013). Participants were assigned to either the mind wandering or mindfulness meditation conditions. Participants in the mindfulness meditation condition participated in focused breathing, while those in the mind wandering condition were told to let their thoughts go where their mind takes them. Participants engaged in these meditations while fMRI was used to acquire neural activation data. Participants also completed the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), a trait mindfulness scale used to determine the participants' everyday mindfulness levels.

The researchers found that in the mind wandering condition, neural regions associated with daydreaming, thoughts related to self, and lapses in attention were activated (medial prefrontal cortex, dorsomedial prefrontal cortex, angular gyrus and precuneus). In contrast, those in the mindfulness meditation condition showed activation in areas of the brain linked with attentional control (superior parietal lobule and temporal-parietal junction), attention to sensory information (pre-supplementary motor area and dorsal anterior cingulate gyrus), and awareness of bodily sensations (insula). The hippocampus and caudate also showed increased activation among those in the mindfulness meditation group, areas known to be related to memory and rewards, respectively (Taren, Creswell, & Gianaros, 2013). Finally, the researchers found that the additional activation in the dorsolateral prefrontal cortex, temporal-parietal junction, and superior parietal lobule – brain regions linked to the control of attention – was associated with higher trait mindfulness scores. The results indicated that there was an interaction between the experimental conditions of the participants and their brain activation, and that this interaction was moderated by trait mindfulness. The researchers concluded that brain regions associated with attentional processes are employed when novice participants participate in mindfulness meditation (Dickenson et al., 2013).

Ruocco and Direkoglu (2013) also explored the relationship between mindfulness and attention (specifically, sustained attention and working memory). Previous research suggested that increased trait mindfulness was linked to better performance on sustained attention tasks (Mrazek, Smallwood, & Schooler, 2012; Rosenberg, Noonan, DeGutis, & Esterman, 2013). The experiment Ruocco and Direkoglu conducted used the Philadelphia Mindfulness Scale to measure trait mindfulness, which includes items meant to determine present-moment awareness and acceptance (Cardaciotto, Herbert, Forman, Moitra, & Farrow, 2008). Two tasks (i.e., the Conners' Continuous Performance Test-II and the Penn Letter N-Back Test) were used to measure sustained attention and working memory, respectively (Conners, 2000; Ragland et al., 2002). Correlations were found between mindfulness levels and sustained attention and working memory scores, suggesting relationships between the constructs of mindfulness, attention, and memory. Especially pertinent to the topic explored in this paper, a link was found between the awareness subscale of the mindfulness measure and the sustained attention measure, with greater mindfulness being related to increased attention. This indicates that as mindfulness increases, attention may increase, as well, which helps validate the definition of mindfulness.

Attention has not only been related to mindfulness, but also to time perception. One study established the link between attention and time perception by comparing children with Attention-Deficit/Hyperactivity Disorder (ADHD) and children without ADHD (Mullins, Bellgrove, Gill, & Robertson, 2005). These children completed time reproduction tasks, and results indicated that when matched with the children from the control group, the children with ADHD performed worse. The time reproduction tasks consisted of a stimuli being presented for a duration of time, and then disappearing. Participants then “reproduced” this duration by causing the stimuli to appear on a computer screen for a perceived equal length of time.

The researchers discovered that children who had ADHD showed greater variability in the size and direction of the errors they made in their judgments of time reproductions. Thus, children with lower attentional abilities were less accurate in their perception of time. The conclusions of the study supported the idea of a link between attention and time perception – specifically, sustained attention and time reproduction. Although this study found an important relationship between attention and time perception, a limitation of this study is that it used an abnormal population (children with ADHD). Manipulating attention in participants instead of using an ADHD sample may have resulted in findings that are more generalizable to a typical population.

Tasks measuring one’s ability to accurately produce time periods and to discriminate between time segments can be used to better assess the experience of time. A group of researchers were interested in evaluating time perception in patients with traumatic brain injury (TBI), and used these two additional methods, as well as time reproduction, to measure time perception in their participants (Mioni, Mattalia, & Stablum, 2013). These tasks were considered “temporal,” while tasks measuring attention, working memory, and executive functions were considered “neuropsychological assessment tasks.” Two different measures were used to assess each of the following neuropsychological abilities: attentional abilities, working memory, and executive function. Participants in the study were patients with TBI and matched healthy control participants.

The results suggested that time reproduction was correlated with all neuropsychological assessment tasks – attention, working memory, and executive function. Time discrimination, however, was correlated with only one measure from each of the neuropsychological assessments. The investigators concluded that decreased performance on the temporal assessment tasks is related to problems with attention, working memory, and executive function (Mioni et al., 2013). Thus, this study adds to the findings of Mullins et al. and solidifies the notion that time perception is associated with attention. However, this study also used an atypical sample (people with traumatic brain injury), which can be viewed as a limitation. It is important to evaluate whether attention and time perception are linked in less abnormal populations.

As a state of increased attention, mindfulness appears to be an important factor in one's experience of the passing of time. Previous research has somewhat explored this notion, but mostly in terms of mindfulness and time affluence. Time affluence is the extent to which one feels one has a sufficient amount of time to complete the task at hand, or how "wealthy" in time one feels. Researchers found that time affluence is positively correlated with one's well-being, and that mindfulness mediates these two variables (Kasser & Sheldon, 2009). That is, increased time affluence is related to greater well-being, and people who are more mindful typically report greater time affluence.

In another study on the topic, investigators explored the relationship between mindfulness and time affluence in a study of work commuters (LaJeunesse & Rodriguez, 2012). They measured mindfulness with the MAAS (Brown & Ryan, 2003), and time affluence through the Material Affluence Time Affluence Scale (Kasser & Sheldon, 2009). Additionally, they collected data on journey-based affect, which encompassed information about commuting stress, competence, and attunement. LaJeunesse and Rodriguez defined commuting attunement as the feelings of relaxation and satisfaction one experiences while commuting. They found that mindfulness increased attunement while commuting, and that this relationship was mediated by competence, stress, and time affluence. According to the study's preferred model, competence and time affluence were both positively associated with mindfulness and attunement, while stress was negatively linked with mindfulness and attunement. One major shortfall of this study was that it used only self-reported measures, and no behavioral measures.

The previously discussed research suggests that mindfulness and time perception are related, and one study suggests a way in which this relationship may work (Sauer et al., 2012). The study was designed to measure subjective temporal processing through perceptions of a Necker Cube. The researchers hypothesized that meditation would lengthen the duration of "now," and that the duration of "now" would be associated with mindfulness. The Necker Cube is a visual stimulus shaped like a three-dimensional cube, which can be perceived in two different ways – by viewing either the lower-left face of the cube or the upper-right face of the cube as being closer to the perceiver. In other words, one can perceive either the lower-left side or the upper-right side as being the front of the cube. Participants were categorized into either a mindfulness meditation experts group or a matched control group, and the Mindful Attention Awareness Scale (MAAS) was used to evaluate participants' trait mindfulness (Brown & Ryan, 2003). In order to measure perception of time, participants were asked to report how often they experienced a change in cube perspective (during the first 3 minutes of the session), and then were asked to hold the same perspective for as long as possible.

Sauer et al. found that meditators were able to hold the same perspective for a significantly longer amount of time than the control group. They also examined the MAAS data and discovered that there was a positive correlation between mindfulness and the length of time that the same perspective was held. Since the MAAS data was collapsed across the meditator group and the control group, this finding indicates that trait mindfulness, and not only the active engagement in mindfulness meditation, can be associated with the amount of time a perspective can be held. The researchers concluded that the subjective feeling of "now" – as measured by the time a perspective is held – is longer for meditators than non-meditators, and that mindfulness may be the construct that mediates this effect since greater trait mindfulness was linked with a longer perception of "now". However, one problem with this study is its use of the Necker Cube as its main time perception measure. There may be other available measures that can quantify time perception in a more valid way. The validity of the Necker cube to measure time perception may be limited or confounded by variables such as attention and boredom.

A recent experiment[1] investigated the relationship between mindfulness and time perception, with a temporal bisection task to assess time perception (Kramer, Weger, & Sharma, 2013). The researchers used the bisection task as a pre-test for each participant, and then as a post-test after each participant completed either a meditation induction or an audiobook listening task (the control condition). The researchers concluded that mindfulness meditations alter time perception by causing time to seem longer. Although this finding presents an experimental effect of mindfulness and time perception, a limitation of this study is that it only used one type of behavioral measure to test time perception. Additionally, the researchers found no significant

[1] This study was published in September of 2013, after the current study was developed and underway.

correlations when they compared participant scores on mindfulness questionnaires (the Trait Mindful Attention Awareness Scale and the Five Facet Mindfulness Questionnaire) with bisection task scores. Thus, they could only conclude that state mindfulness (as manipulated by the condition into which each participant was placed), and not trait mindfulness, was associated with time perception.

The Current Study

This study seeks to further this area of research by addressing the question of whether the increased attention and awareness that characterizes mindfulness can be related to a different perception of time, as measured by both self-report and varied behavioral tasks. One of the self-report methods we used was a measure of time affluence, or how “wealthy” in time a person feels. Time affluence and stress have been negatively linked through previous research (LaJeunesse & Rodriguez, 2012), and time affluence and well-being have been positively associated (Kasser et al., 2009), so the current study has implications for a potentially important mechanism of mindfulness towards well-being, i.e., time perception.

Prior research has found that trait mindfulness and time perception are linked, “now” is longer for mindfulness meditators than non-meditators (Sauer et al., 2012), and that mindfulness meditations make participants perceive time as longer (Kramer et al., 2013). Thus, our first hypothesis was that individuals higher in mindfulness would experience a “stretching” or “slowing down” of time because of their increased awareness, as previously demonstrated by research. We extend upon this previous literature by utilizing four behavioral measures of time perception drawn from the time perception literature. We proposed the use of four behavioral time perception measures, instead of only one, in order to ensure the validity and reliability of our methods and findings. Greater attention has been previously associated with less variability of errors in time perception judgments, and mindfulness can be partially defined as increased attention (Mullins, et al., 2005). Therefore, our second hypothesis was that people with greater mindfulness were also expected to be more accurate in their perception of time, due to higher attention associated with mindfulness.

Methods

Participants

Participants were recruited though the University of North Carolina at Chapel Hill's Psychology 101 participant pool. Participants were seventy UNC Chapel Hill undergraduate students (17 males and 53 females). Participants' ages ranged from 17 years to 21 years, and the majority were either 18 or 19 years old. The sample's race/ethnicity breakdown was as follows: 71.8% White/Caucasian, 9.9% Black/African American, 7.0% East Asian (i.e., Chinese, Japanese, Vietnamese), 2.8% South Asian (i.e., Indian, Pakistani, Burmese), 1.4% Pacific Islander/Native Hawaiian, and 5.6% Other. One participant chose not to report his/her race.

Measures

Perception tasks. Each participant completed a total of twenty-eight trials of four different time perception tasks. Each task is described in more detail below. Participants engaged in three different production trials, three different estimation trials, one reproduction trial, and two comparison trials. Each time perception trial was repeated a second time, and thus participants completed a total of eighteen time perception trials. Ten filler trials were included in the perception segment, but were not repeated. All tasks were randomized, so each participant experienced them in a different order. Time perception and filler trials were randomly distributed throughout the perception task. Filler trials were used to ask participants questions about the size and color of a box or triangle stimulus, and about the length or direction of a line segment stimulus (see Appendix for images). These were included in order to prevent participants from realizing that the primary construct being analyzed by the perception task was time perception. Descriptive statistics about different duration's averaged trials for production and estimation can be found in Table 1.

Time estimation. In the time estimation trials participants viewed a stimulus, a gray two-dimensional box on the screen, which appeared for 1250, 2500, or 3250 milliseconds (see Appendix for image). Participants were instructed to approximate the duration that the box was shown on the screen in seconds, and they were allowed to use decimals to indicate fractions of a second. Scores were calculated by creating a weighted average of the three types of trials (1250 ms, 2500 ms, and 3250 ms). An average of two trials for each time period was calculated, and then these scores were added and divided by 7000 ms (the sum of 1250, 2500, and 3250 ms). This determined each participant's Weighted Average Estimation score.

Time production. During the time production trials, each participant was asked to produce 1, 3, or 5 seconds. Each participant was asked to first press the space bar to start the timer, and was shown a green 'play' symbol to indicate that the duration had started. Then, the participant pressed the space bar again to stop the timer, and was shown a blue 'pause' symbol to indicate that the duration had stopped (see Appendix for green 'play' symbol and blue 'pause' symbol). Weighted Average Production scores were calculated by computing an average for each trial type (1 second, 3 seconds, and 5 seconds). Then these scores were added and divided by 9 (the sum of 1, 3, and 5 seconds). This determined the Weighted Average Production value for each participant.

Time reproduction. Time reproduction trials were comprised of the stimulus (a gray box, as used in time estimation trials) being presented on the screen for 2500 milliseconds, followed by the prompt to reproduce the duration of time that the box was on the screen. Participants pressed the space bar to start the timer, and were shown the gray box in order to be sure that the interval had started. Then, they pressed the space bar again to stop the timer, and the gray box disappeared so they would be sure that the interval had ended. Participants' recorded time periods were averaged across the two trials they completed, resulting in Average Reproduction scores.

Time comparison. Time comparison trials were formatted as follows: a gray box was shown on the screen, labeled 'Box 1' (presented for 500 or 625 milliseconds), followed by another box, labeled 'Box 2' (presented for 500 or 625 milliseconds – whichever duration was not used for Box 1). Then, participants were instructed to indicate which box was on the screen for a longer duration, Box 1 or Box 2, by pressing the numbers on the keyboard (see Appendix for images of stimuli). Due to the change in presentation order, participants completed two different trials, each repeated twice: two trials of 500-625 milliseconds, and two trials of 625-500 milliseconds. Since participants were asked to identify which of the stimuli was on the screen for a longer duration during each of the four trials, answers were either correct or incorrect. Responses were coded using the following ratings: incorrect = 0 and correct = 1, yielding four recoded values per participant. These were then averaged to produce Comparison Accuracy proportions.

Five Facet Mindfulness Questionnaire (FFMQ). The Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) was used to assess trait mindfulness. Participants were instructed to rate each of the thirty-nine questionnaire items using the provided scale, and to select the responses that best described what was generally true for them. The scale ranged from 1 (never or very rarely true), to 5 (very often or always true).

Items on the questionnaire included statements such as “I think some of my emotions are bad or inappropriate and I shouldn’t feel them” and “I am easily distracted.” These items were used to calculate participants’ trait mindfulness, and have demonstrated construct validity and reliability in previous research (Baer & Williams, 2008). The Cronbach’s Alpha for the current study’s sample size was 0.845 for the FFMQ. The questionnaire can be divided into five facets or subscales: Observe, Describe, Non-judging of inner experience, Non-reactivity to inner experience, and Acting with awareness.

Carolina Empirically Derived Mindfulness Inventory (CEDMI). The CEDMI items consisted of two subscales of the FFMQ, as well as six Difficulties in Emotion Regulation Scale items. When filling out this scale, participants were asked to answer based on which responses best represented them. The scale ranged from 1 (almost never, 0-10%), 2 (sometimes, 11-35%), 3 (about half the time, 36-65%), 4 (most of the time, 66-90%), to 5 (almost always, 91-100%). The DERS questionnaire included items such as “When I’m upset, I become angry with myself for feeling that way” and “When I’m upset, I become embarrassed for feeling that way” (Gratz & Roemer, 2004). Internal reliability for this scale proved sufficient in prior research (Coffey, Hartman, & Fredrickson, 2010), and our study found a Cronbach’s Alpha of 0.776. Responses to the Difficulties with Emotion Regulation Scale items were averaged with the responses to the FFMQ Observe and FFMQ Non-judging of inner experience subscales in order to calculate CEDMI values for each participant (Coffey, Hartman, & Fredrickson, 2010).

Trait Mindful Attention Awareness Scale (Trait MAAS). The Trait MAAS consists of fifteen items anchored on “day-to-day experiences” (Brown & Ryan, 2003). Included in the questionnaire were statements such as “I find it difficult to stay focused on what’s happening in the present.” Participants rated these items on a scale of 1 to 6 (1 = almost always, 2 = very frequently, 3 = somewhat frequently, 4 = somewhat infrequently, 5 = very infrequently, 6 = almost never). This questionnaire is used to measure participants' trait mindfulness, and has demonstrated both reliability and validity in previous studies (Brown & Ryan, 2003; Carlson & Brown, 2009; Montes, Ledesma, García, & Poó, 2014). The current study found a Cronbach's Alpha value of 0.836 for the questionnaire.

State Mindful Attention Awareness Scale (State MAAS). The State Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) was used to ask about state mindfulness, and was adapted to be anchored to the perception tasks. Participants were instructed to answer the items based on their experience during the perception tasks, and to be honest and treat each of the items as separates from the others. The scale ranged from 0 (not at all), 1, 2, 3 (somewhat), 4, 5, to 6 (very much). Items on the questionnaire included statements such as "During the perception tasks: I found it difficult to stay focused on what was happened in the present" and "During the perception tasks: I rushed through the activities without really being attentive to them." This is a validated questionnaire used to measure state mindfulness (Brown & Ryan, 2003), and we calculated a Cronbach's Alpha of 0.822 for State MAAS.

Time Affluence Scale (TAS). The Time Affluence Scale was composed of the eight-item subscale from the validated Material and Time Affluence Scale (MATAS; Kasser & Sheldon, 2009). This scale was meant to measure subjective perceptions of how "wealthy in time" a person feels. The scale ranged from 1 (strongly disagree) to 5 (strongly agree). Questionnaire queries included items such as "My life has been too rushed" and "I have been able to take life at a leisurely pace." Scores for the TAS were calculated by reverse coding the appropriate items (#2, #4, #5, #7) and then averaging the eight item responses for each participant. Higher values on the TAS represented low time affluence, and the scale reliability was 0.793 (Cronbach's Alpha).

Time Perception Questionnaire (TPQ). The three items were developed to measure the participants' subjective experiences of time during the study. The first item stated: "Write 1-2 sentences about how the passage of time felt for you during the various perception tasks you completed." The second and third items were "Reflect on what you just wrote about how the passage of time felt for you during the various perception tasks you completed. Did time feel slower or faster than usual or about the same as usual?" and "Across the whole course of the study, did it feel like time was moving slower or faster than usual or about the same as usual?" These two questions were answered using the following scale: 1 = slower than usual, 2, 3 = about the same as usual, 4, and 5 = faster than usual.

The TPQ was broken down into two parts: one comprised of the two questions involving Likert-Scale responses, and another of the open-response question. The two questions with scale measurements were averaged for each participant, resulting in an Average TPQ score. Faster time perception was exhibited through higher Average TPQ scores. The scale reliability – measured through Cronbach's Alpha – was 0.921 for this scale-response questionnaire. Additionally, two independent researchers coded the open-response question for "slower", "about the same as usual," or "faster" words that participants used in their replies. Subjective perceptions of time were determined for each person based on the following scale: 1 = very slow, 2, 3 = about the same as usual, 4, 5 = very fast. An average of the two coded values was calculated to represent Coded TPQ for each participant, with greater values indicating faster time perception. The inter-rater reliability analysis of the coding found a Cohen's Kappa of 0.721. This is considered substantial agreement, and thus reliability, between raters. A strong positive correlation was found between Average TPQ and Coded TPQ. This means that when self-reported time perception (centered on the study) became faster, time perception (centered on the study), as coded by the researchers, increased.

Demographics. The demographics questionnaire asked participants about their gender, age, education completed, marital status, race or ethnicity, and primary language. Additionally, the final question asked, "What do you think was the point of the study?" to identify participants who may have deduced our hypotheses and constructs of interest (mindfulness and time perception, specifically). No participants reported that they believed the study to be directly about mindfulness and time perception. However, we ran correlations while excluding participants #12, #38, #39, and #46 from all questionnaires and tasks (in addition to participants that we excluded for other reasons, which can be referenced in Footnote 2). These four participants came closest to deducing the purpose of our study. The results from these correlations can be found in Table 2. We felt that the differences in results were negligible, so the results discussed in this paper are those found while not excluding the four additional participants.

Procedures

Before arriving at the lab, participants completed the Trait Mindful Attention Awareness Scale online through the Sona website (MAAS; Brown & Ryan, 2003), as well as some items regarding gender, race/ethnicity, and other demographic questions.

Once at the lab, each participant underwent the consent procedure for the study and was told he or she could leave the session at any time if uncomfortable. Next, the computer prompted the participant to begin the perception task, which included time production, time estimation, time reproduction, time comparison, and filler trials. Each participant was asked to complete questionnaires once the perception task was completed. These included the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004), the State Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006), and the Time Affluence Scale (adapted from Kasser & Sheldon's 2009 Material and Time Affluence Scale). At this point in the study, the participant responded to the Time Perception Questionnaire and demographics questionnaire. The participant read an in-depth debriefing on the computer, and after the researcher gave a short verbal debriefing, the participant left the lab.

Results

Preliminary calculations

All time perception task data will be presented in seconds. Additionally, in instances when participants did not respond to time perception or mindfulness measures, these participants were automatically excluded from analysis by SPSS for the specific measure that they did not complete. One participant did not complete the Trait MAAS prescreen items, and was thus excluded from the Trait MAAS data.

Weighted averages for some of the tasks were computed in order to calculate a more stable measure for each participant since they better account for responses across different time lengths of the same tasks. Weighted averages were computed by averaging each participant's response for each time period for each trial (for example, calculating averages for the 1, 3, and 5 second time periods for Production). Then, these averages were added together and divided by the total of the true value for each task (for example, adding 1, 3, and 5 seconds for a total of 9 seconds). Therefore, if – theoretically – a participant's time perception were completely correct during each trial, they would receive a score of 1.0 as their weighted average. For example, if this participant was completing the Production task, he or she would have averages of 1, 3, and 5 seconds for each time period, and then these would be added for a total of 9 seconds. Then, 9 would be divided by the total of the true added scores (also 9 seconds), and the participant would receive a score of 1.0. Since each task is a different measure of the underlying construct of time perception, we expected people to have "trait" under- or over- estimation, production, or reproduction values. Thus, we thought that people who under-estimated would also under-produce and under-reproduce, and that people who over-estimated would also over-produce and over-reproduce.

We used both "length" and "accuracy" variables to investigate our hypotheses. The duration of responses for the production, estimation, and reproduction tasks served as the "length" variables used to explore our first hypothesis that greater mindfulness would be associated with a longer perception of time. "Accuracy" variables were used to assess our second hypothesis that increased mindfulness would be linked to a more accurate perception of time. We calculated "time perception accuracy" for the time perception tasks by assessing the average distance from the "true value" of a task for each participant by subtracting average responses (for Estimation, Production, and Reproduction) from true stimuli time durations for each of the tasks, and then taking the absolute value of the result. We termed these values "Absolute Difference" scores.

Coded Time Perception Questionnaire. Participants' responses were at times difficult or impossible to code due to the response being off-topic, and not involving time in an understandable way. In those cases, each of the two researchers could choose to refrain from coding the responses. If one researcher coded a response, and the other chose not to do so, the participant's data for the open-response item of the TPQ was excluded from analysis. Thus, a sample size of fifty resulted for this particular measure.

Time perception tasks. Some participants' data was excluded for the time perception tasks.[2]

Statistical Analyses

In order to test our first hypothesis – that increased mindfulness would be related to a slower perception of time – Pearson's correlations were conducted between scores on the mindfulness measures (FFMQ, Trait MAAS, CEDMI, and State MAAS), the time perception self-report measures (TAS and TPQ), and time perception tasks (Estimation, Production, Reproduction). All correlations and descriptive statistics can be found in Table 3.

A few of our findings supported our first hypothesis. We found that FFMQ and TAS scores were negatively correlated, meaning that as trait mindfulness increased, time affluence increased, $r(68) = -.29$, $p = .014$ (recall that lower TAS scores reflect greater time affluence). Another finding – a trend – indicated that as state mindfulness (measured by the State MAAS) increased, time perception (measured by Weighted Average Production) lengthened, $r(67) = .23$, $p = .062$. Contrary to hypothesis 1, neither trait nor state mindfulness significantly predicted longer perceptions of time based on our behavioral task measures (see Table 3).

A few unexpected findings were encountered in the course of our analyses. When we examined the relationships between self-reported time perception and mindfulness, we found that

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[2] We excluded the first participant's time perception task data (except for the Comparison task) due to potential confusion during task instructions. Thus, we modified the task instructions for all subsequent participants. Additionally, data from participants #30 and #35 were omitted from the time reproduction task data since their values for Average Reproduction were outliers for this measure (more than three standard deviations away from the mean, $M = 3.60$, $SD = 3.77$).

Average TPQ and State MAAS were positively correlated, $r(68) = .34$, $p = .004$. Coded TPQ also showed a positive correlation with State MAAS, $r(48) = .34$, $p = .015$. In both cases, as state mindfulness increased, both measures of state time perception became faster or "shortened." In terms of links between mindfulness and time perception tasks, we found a negative trend between FFMQ and Estimation, which means that as trait mindfulness increased, estimation values decreased, $r(67) = -.23$, $p = .063$. A few surprising trends were discovered, linking self-report measures and time perception tasks. These can be referenced in Table 3.

We conducted correlations between each of the FFMQ subscales and all of the self-reported time perception and time affluence scales, as well as the behavioral time perception tasks. A significant negative relationship was found between FFMQ Describe and Estimation, adding to our previous finding that FFMQ total scores and Estimation were related, $r(67) = -.29$, $p = .015$. We also found that FFMQ Observe and average TPQ were negatively linked, such that higher Observe scores were linked with a more lengthened perception of time, $r(68) = -.26$, $p = .031$. The TAS had a negative relationship with three subscales: Describe, $r(68) = -.24$, $p = .046$, Non-reactivity to inner experience, $r(68) = -.25$, $p = .037$, and Acting with awareness, $r(67) = -.28$, $p = .021$. As scores in each of these subscales increased, participants felt more time affluent. All correlations for the FFMQ subscales can be found in Table 4.

Finally, correlations between the time perception tasks were conducted, and a significant result was detected between Estimation and Production, which revealed that as estimation scores increased, production values decreased, $r(68) = -.27$, $p = .023$. We also observed some surprising trends having to do with the time perception tasks, which were unrelated to our hypotheses about mindfulness (see Table 3).

When we ran correlations for our second hypothesis – which stated that increased mindfulness is associated with a more accurate perception of time – using Absolute Difference scores, no significant findings emerged.

Discussion

We hypothesized that people higher in mindfulness would have a longer and more accurate perception of time than people lower in mindfulness. Some of our findings supported the notion that greater mindfulness is linked with a longer perception of time, but no evidence was found to support the idea that higher levels of mindfulness are related to more accurate perceptions of time.

Two main results supported our hypothesis that as mindfulness increases, time perception slows, and time becomes "stretched." We found that trait mindfulness was associated with higher perceived time affluence. We also found that, on a trend level, as state mindfulness increases, time perception (as measured by the production task) becomes lengthened.

The TAS measured what could be called "trait" time affluence. In other words, its items related to participants' daily lives and overall "wealth" in time, whereas the TPQ items were centered on time perception during the study, specifically ("state" time perception). Therefore, the relationship between the FFMQ (trait mindfulness) and TAS ("trait" time affluence) supported the notion that people higher in trait mindfulness experience everyday life in a less rushed and more time affluent manner than those lower in trait mindfulness. This finding replicates the associations found between mindfulness and time affluence by Kasser and Sheldon (2009) and LaJeunesse and Rodriguez (2012).

The trend observed between State MAAS scores and Production values is consistent with our hypothesis that as mindfulness increases, time perception becomes lengthened. It is important to note, however, that this trend only applied to state mindfulness, and that it only became apparent for one of the four time perception tasks, and thus may be a spurious finding. Future research should replicate and further evaluate the relationship between state mindfulness and production.

We hypothesized that more of our behavioral and self-reported measures would have connections with mindfulness. Our expectation was for both state and trait mindfulness measures to have relationships with production, reproduction, estimation, time affluence, and time perception such that greater mindfulness would be linked with a slower perception of time. However, we did not find evidence of many of these relationships with the specific measures that we used.

Interestingly, none of our time perception tasks (Estimation, Production, Reproduction, or Comparison) were associated with the TAS. This suggests that the feeling of having enough time does not seem to be related to actual perception of time based on our behavioral measures. This result may be due to the fact that the tasks measured time perception during the study, while the TAS measured time affluence over one's life ("trait" time affluence). Given our findings, we recommend that future research utilize different types of measures of time perception, including a variety of behavioral measures that are less perception-based and focus more on participants' subjective sense of time.

Some significant findings did not fit our first postulates. First, we found that as state mindfulness increased, state time perception (as measured by both the Average TPQ and Coded TPQ) became faster. This was contrary to our hypothesis that as mindfulness increased, time perception would become slower. Perhaps as participants' state mindfulness increased, they felt more focused on the tasks at hand, and therefore felt that time was going by faster during the study due to their absorption in the tasks. They may have lost track of time due to their increased attention, and therefore felt, at the end of the study, that time had gone by quickly. It also may be the case that when participants are high in mindfulness and are enjoying the task at hand, or are paying a great deal of attention to it, “state” time perception quickens, or as the popular phrase communicates, “time flies when you’re having fun.” Thus, it is possible that the psychological concept of flow may be at play in this relationship.

Flow is defined as an increase in focus and enjoyment during a task that results in intense concentration, and often a loss of sense of time (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005). The research literature on flow suggests that when people are absorbed in a task, they may feel that time speeds up for them (Schmidt, Shernoff, & Csikszentmihalyi, 2007; Shernoff, & Anderson, 2013). Additionally, one study found a link between cognitive flexibility, mindfulness, and flow when gender, age, and history of mindfulness among participants were held constant (Moore, 2013). The study’s results indicated that cognitive flexibility and mindfulness predict disposition for flow, and that greater mindfulness may be linked with greater flow. These findings indicate that perhaps people higher in mindfulness experienced more flow in the course of the study session, and thus felt that time had gone by at a fast rate during the study.

We interpret the finding between state mindfulness and state time perception with caution, however, as the TPQ was designed for the current study and has not been formally validated. Furthermore, it is possible that confounding variables such as attention, enjoyment, and social desirability may be involved with the association of TPQ and mindfulness. Since the State MAAS items are anchored on the study, and focus on self-reported attention, we believe that participants might adjust their responses to imply that they were paying more attention to the study than they really were, thus biasing their state mindfulness scores. We propose that future studies focus on these possible confounding variables, as well as replicate this finding.

When we analyzed the relationships between he FFMQ subscales and our other measures, we found some significant results. The finding that as FFMQ Describe scores increased, Estimation scores decreased supported the unexpected trend that FFMQ and Estimation were negatively associated (see Table 3). However, a few of our findings supported our first hypothesis. As FFMQ Observe values increased, participants' time perception slowed (as measured by average TPQ). This supported the notion that as mindfulness increases, time perception becomes "stretched." However, this only applied to the Observe subscale of the FFMQ, and not to the total FFMQ scores. There were three additional significant findings, relating FFMQ subscales to the TAS. We found that as FFMQ Describe scores increased, time affluence increased, too. The same finding applied to FFMQ Non-reactivity to inner experience and Acting with awareness. This supported our previous finding that total FFMQ scores and TAS values were significantly correlated. In general, as trait mindfulness (as measured by the FFMQ) increased, time affluence became greater.

We came across a statistically significant finding that caused us to reconsider our measures. We expected that participants' behavior during the time perception tasks would reveal trait-like tendencies to consistently over-estimate and over-produce or under-estimate and under-produce during the tasks. However, we found that as estimation values increased, production times decreased. In other words, as one measure of time perception became greater or "lengthened," a different measure because "shortened." This finding calls into question the validity of our time perception task measures. Prior studies have found that varying behavioral measures of time perception elicit significant differences in accuracy and variations of durations

(Pande, Shindey, Parganiha, & Pati, 2013), and that these differences are due to the distinctive brain regions activated during each task (Coull, Davranche, Nazarian, & Vidal, 2013). This may be one reason that our time perception tasks did not produce trait-like tendencies across the tasks, and could be a potential limitation of the tasks previously used in the time perception literature. If each participant did not score similarly (in the same direction – under or over – and with comparable accuracy) on these widely used time perception tasks, some of these tasks may not be accurate measures of the construct of interest, time perception. Future studies should explore which of the tasks best measures time perception.

We propose post-hoc that the negative correlation between Estimation and Production also may be due to boredom: participants who were bored may have over-estimated the length that the stimuli were presented because the presented durations felt long to them, and under-produced the length of the stimuli because they were trying to get through the production tasks as quickly as possible.

However, we did not take into account that the duration of each task may affect the over- or under-estimations or productions. A potential confounding variable in our study may be that we chose production times of 1, 3, and 5 seconds, and estimation durations of 1250, 2500, and 3250 milliseconds, which resulted in different patterns of production and estimation. A study by Mioni, Mattalia, and Stablum (2013) found that participants in both the control and traumatic brain injury groups over-reproduced the reproduction tasks that were 500 milliseconds long, while they under-reproduced the reproduction tasks that were 1000 or 1500 milliseconds long. Thus, it may be the case that our production durations (1 second, 3 seconds, 5 seconds) and estimation durations (1250 ms, 2500 ms, 3250 ms) caused participants to over- or under-estimate or produce differently. Perhaps we would have found a positive relationship between estimation and production if our time durations for each had been consistent (1250, 2500, and 3250 milliseconds for both tasks). When we analyzed mean scores for trial durations, we found that participants over-produced all durations except the trials for the production of 3 seconds. Participants also over-estimated all estimation durations (see Table 1).

Another potential problem with estimation measures in general is that they produce a greater amount of variability than production and reproduction. This is because participants tend of "round off" their estimations (Mioni et al., 2012). If future researchers choose to use production and estimation as their behavioral measures, we suggest that they use the same time durations for each of these measures. If estimation tasks durations are 1250 milliseconds, 2500 milliseconds, and 3250 milliseconds in length, then production tasks should ask participants to produce the same time durations. Thus, the results could indicate whether participants produce and estimate durations in the same way, or whether they over-produce and under-estimate consistently (or vice versa).

The problem highlighted by the negative correlation of the estimation and production tasks could also lie in the calculation of the time perception tasks themselves: we may have masked certain effects by calculating weighted averages for each task. Therefore, we also analyzed different durations for all tasks without creating weighted averages, but we only found one significant result.[3] We explored correlations between specific time durations for each

[3] Correlations between specific task durations and mindfulness measures revealed one significant finding between State MAAS and Average Production of 3 seconds. This was a positive correlation, and indicated that as state mindfulness increased, production of 3 seconds increased, too. However, since this was the only duration (of either production or estimation) that resulted in a relationship with mindfulness, we believe this may be a spurious finding.

measure and mindfulness, time perception, and time affluence measures in order to explore whether or not different time durations had varying relationships with these measures.[4]

There are a few limitations to our study. First, due to time constraints, we conducted a correlational study, instead of an experimental one. An experimental procedure could have stronger implications for the mindfulness field. This would be due to the researchers' abilities to draw conclusions about causal relationships between variables that produce significant results. A possible future study could make use of an experimental procedure by manipulating mindfulness in participants. If there were two conditions – a mindfulness induction and a mind-wandering induction – we could see if those in the mindfulness condition had a longer and more accurate perception of time, on average, across their daily lives than those in the mind-wandering condition. Since we cannot be sure how long inductions will "last," future research could test a mindfulness meditation training group and compare it to a control group in order to explore the effects of bigger "doses" of mindfulness, and whether these doses cause changes in time perception. The behavioral tasks were especially cognitively demanding, and we believe this may have influenced time perception. We suggest that future studies take measures of potentially confounding variables such as social desirability, attention, boredom, enjoyment, and flow.

Further research may also benefit from using different behavioral tasks that are less demanding and measure "trait" time perception instead of a more limited "state" perception of

[4] The relationships between time perception tasks were not as expected. Correlations were performed between time perception tasks, and we found a weak positive trend between Production and Comparison: as production durations increased, comparison task accuracy increased, as well. We predicted that increased mindfulness would be associated with both a longer and more accurate perception of time. This finding supports the link between more accurate and longer time perceptions, but does not include the mindfulness component of our theory.

time. This could be achieved through a longitudinal study that uses new time perception measures. An example of a new behavioral measure that could be used in a future study is the Tic-Toc-Trac. Two Cornell University students, Brian Schiffer and Sima Mitra, invented a watch called the Tic-Toc-Trac that can help track one's perception of time. The watch presents the wearer with a randomly chosen numeral from 5 to 55 minutes, and then this number disappears. The wearer is supposed to tap the face of the watch when they believe the presented duration of time has passed. This can be done many times over a long duration – even a year – while the watch records the results. Thus, this could be a good longitudinal behavioral measure of a person's time perception and affluence.

In conclusion, we found partial support for our hypothesis that greater mindfulness is associated with a "stretched" or "lengthened" perception of time. Specifically, we observed that as trait mindfulness increased, time affluence increased, as well. Additionally, as state mindfulness increased, one measure of behavioral time perception lengthened, on a trend level. We did not find that mindfulness was associated with the three other time perception tasks or that increased mindfulness is linked with a more accurate perception of time. We suggest that future studies use experimental manipulations, varying behavioral measures, and test for potential confounding variables to further explore the relationship between present moment attention, or mindfulness, and the perception of the passing of time.

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Table 1

Means and Standard Deviations for Specific Measures

Measure	*M*	*SD*
Average Production 1	1151.20	407.39
Average Production 3	2928.22	743.59
Average Production 5	5021.6594	1174.24
Average Estimation 1250	1480.38	620.13
Average Estimation 2500	2687.46	831.33
Average Estimation 3250	3432.10	1117.63

Note. Average Production 1: Average productions for producing 1 second; Average Production 3: Average productions for producing 3 seconds; Average Production 5: Average productions for producing 5 seconds; Average Estimation 1250: Average estimations for 1250 milliseconds task; Average Estimation 2500: Average estimations for 2500 milliseconds task; Average Estimation 3250: Average estimations for 3250 milliseconds task.

Table 2

Correlations Between Ten Variables, Means, and Standard Deviations for Scores with Extra Exclusions (#12, #38, #39, #46)

Measure	1	2	3	4	5	6	7	8	9	10	11	*M*	*SD*
1. TAS	–											3.40	0.69
2. AvgTPQ	.022	–										2.78	1.10
3. Coded TPQ	.004	.784**	–									2.90	1.34
4. FFMQ	-.301*	.075	.003	–								3.15	0.34
5. Trait MAAS	-.125	.117	.121	.271*	–							3.77	0.61
6. CEDMI	.051	-.039	.091	.532**	-.050	–						2.92	0.27
7. State MAAS	-.242	.325**	.348*	.233^{T}	.226^{T}	.038	–					4.15	1.07
8. Produce	.113	-.182	.084	-.120	.076	-.127	.180	–				1.02	0.23
9. Reprod.	-.076	.025	.116	.193	.061	.159	-.140	-.071	–			3.66	3.88
10. Estimat.	.248*	-.075	-.073	-.218^{T}	-.099	.094	-.115	-.227^{T}	-.012	–		1.08	0.29
11. Compare	.040	.176	.314*	-.147	-.015	-.183	-.036	.169	-.046	.006	–	0.67	0.24

Note. TAS: Time Affluence Scale; AvgTPQ: Average Time Perception Questionnaire scores; Coded TPQ: Coded Time Perception Questionnaire scores; FFMQ: Five Facet Mindfulness Questionnaire; Trait MAAS: Trait Mindful Attention Awareness Scale; CEDMI: Carolina Empirically Derived Mindfulness Inventory; State MAAS: State Mindful Attention Awareness Scale; Produce: Weighted Average Production scores; Reprod.: Average Reproduction scores; Estimat.: Weighted Average Estimation scores; Comparison: Comparison Accuracy proportions.

* $p < .05$

** $p < .01$

^{T} $.05 < p < .1$ (Trend)

Table 3

Correlations Between Ten Variables, Means, and Standard Deviations for Scores without Extra Exclusions

Measure	1	2	3	4	5	6	7	8	9	10	11	*M*	*SD*
1. TAS	–											3.39	0.67
2. AvgTPQ	.03	–										2.79	1.13
3. Coded TPQ	.00	.80**	–									2.95	1.35
4. FFMQ	-.29*	.06	.01	–								3.15	0.35
5. Trait MAAS	-.14	.18	.22	.28*	–							3.81	0.63
6. CEDMI	.02	-.06	.09	.59**	.02	–						2.93	0.29
7. State MAAS	-.20	.34**	.34*	.26*	.22^{T}	.05	–					4.10	1.10
8. Produce	.12	-.15	.09	-.07	.07	-.10	.23^{T}	–				1.01	0.23
9. Reprod.	-.07	.02	.10	.18	.04	.14	-.12	-.06	–			3.60	3.77
10. Estimat.	.23^{T}	-.13	-.11	-.23^{T}	-.12	.06	-.16	-.27*	-.02	–		1.09	0.32
11. Compare	.07	.19	.27^{T}	-.08	-.04	-.14	.05	.21^{T}	-.02	-.02	–	0.66	0.24

Note. TAS: Time Affluence Scale; AvgTPQ: Average Time Perception Questionnaire scores; Coded TPQ: Coded Time Perception Questionnaire scores; FFMQ: Five Facet Mindfulness Questionnaire; Trait MAAS: Trait Mindful Attention Awareness Scale; CEDMI: Carolina Empirically Derived Mindfulness Inventory; State MAAS: State Mindful Attention Awareness Scale; Produce: Weighted Average Production scores; Reprod.: Average Reproduction scores; Estimat.: Weighted Average Estimation scores; Comparison: Comparison Accuracy proportions.
* $p < .05$
** $p < .01$
^{T} $.05 < p < .1$ (Trend)

Table 4

Correlations Between FFMQ Subscales, Self-Reported Measures, and Behavioral Tasks

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1. FFMQ Observe	–											
2. FFMQ Describe	.28*	–										
3. FFMQ Non-judging	-.17	.15	–									
4. FFMQ Non-react	.24*	.13	-.09	–								
5. FFMQ Act aware	.08	.35**	.34**	-.01	–							
6. TAS	-.09	-.24*	.02	-.25*	-.28*	–						
7. AvgTPQ	-.26*	-.07	.21	.01	.21	.03	–					
8. CodedTPQ	-.19	-.27	.26	.09	.09	.00	.80**	–				
9. Produce	.09	.10	-.22	.00	-.13	.12	-.15	.09	–			
10. Reprod.	.08	.02	.15	.18	.08	-.07	.02	.10	-.06	–		
11. Estimat.	.08	-.29*	-.09	-.18	-.14	.23	-.13	-.11	-.27*	-.02	–	
12. Compare	-.09	-.01	-.10	.01	-.02	.07	.19	.27	.21	-.02	-.02	–

Note. FFMQ Observe: Five Facet Mindfulness Questionnaire's Observe subscale; FFMQ Describe: Five Facet Mindfulness Questionnaire's Describe subscale; FFMQ Non-judging: Five Facet Mindfulness Questionnaire's Non-judging of inner experience subscale; FFMQ Non-react: Five Facet Mindfulness Questionnaire's Non-reactivity to inner experience subscale; FFMQ Act aware: Five Facet Mindfulness Questionnaire's Acting with awareness subscale; TAS: Time Affluence Scale; AvgTPQ: Average Time Perception Questionnaire scores; CodedTPQ: Coded Time Perception Questionnaire scores; Produce: Weighted Average Production scores; Reprod.: Average Reproduction scores; Estimat.: Weighted Average Estimation scores; Comparison: Comparison Accuracy proportions.

* $p < .05$

** $p < .01$

Appendix

Figure A1: Box stimuli for Estimation and Reproduction tasks.

Figure A2: “Play” symbol presented during Production task.

Figure A3: “Pause” symbol presented during Production task.

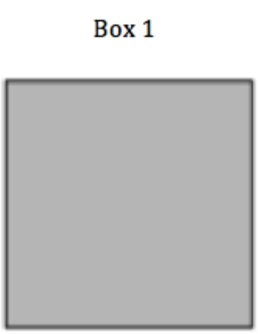

Figure A4: “Box 1” stimuli presented during Reproduction task.

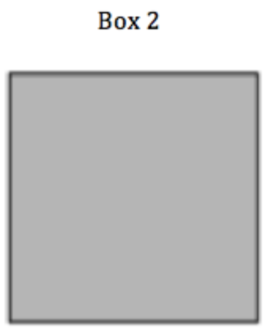

Figure A5: “Box 2” stimuli presented during Reproduction task.

Figure A6: Line stimuli presented as filler task.

Figure A7: Line stimuli presented as filler task.

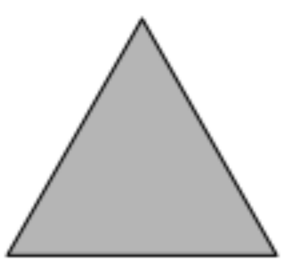

Figure A8: Triangle stimuli presented as filler task.

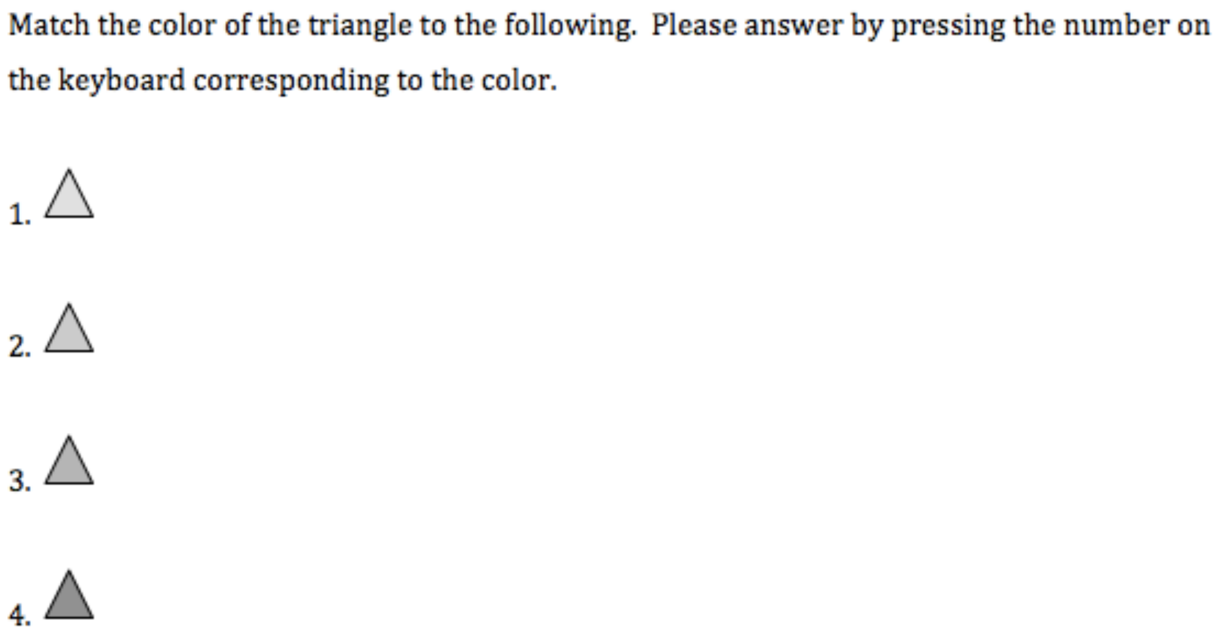

Figure A9: Triangle color comparison item presented during filler tasks.

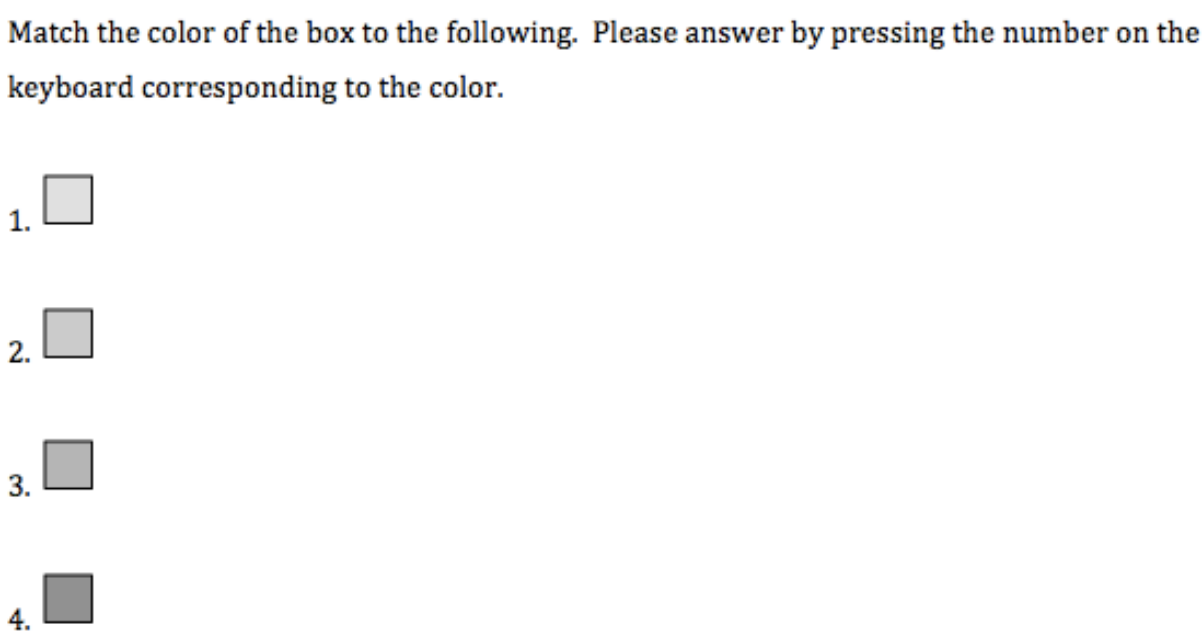

Figure A10: Box color comparison item presented during filler tasks.