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Dealing with the Unknown: Can Mindfulness Help People Tolerate Ambiguity?

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Table of Contents

Abstract

Ambiguity in decision-making has previously been shown to lead to sub-optimal outcomes in decision-making scenarios such as the Ellsberg Urn experiment. There has been a lack of studies on whether it is possible to change how a person deals with ambiguity and whether it can improve decision-making as a result. With intolerance to ambiguity having been linked to vaccine hesitancy (Ritov & Baron, 1990), finding a way to make people more tolerant of ambiguity has societal relevance. This paper investigates if mindfulness meditation can increase a person's ability to deal with ambiguity. To test this, a randomised control study was performed with the treatment group asked to perform daily mindfulness meditation for a week using the app, 'Headspace'. An active control was used for this experiment using the cognitive brain training app, 'Luminosity'. At the end of the intervention the subjects participated in an online Ellsberg Urn experiment and filled out a survey to measure how they dealt with ambiguous scenarios. No significant differences were found between the treatment and control for any of the output measures. It is concluded that short-term mindfulness intervention does not affect how an individual responds to ambiguity. Further long-term studies are needed to see if there is an effect of mindfulness on how people deal with ambiguity.

Introduction

Mindfulness programs have recently made headways in the corporate world to help improve employee well-being, with companies such as Google and Unilever implementing mindfulness programs (Parcerisa, 2019; Unilever, n.d.). Not only have mindfulness programs long been associated with reducing stress and anxiety, but they are also potential channels to improve decision making (Raglan, 2014). In this paper I investigate a specific domain of decision-making, decisions under ambiguity, and the potential for mindfulness to lead to better decision-making in this domain. I look at ambiguity from both an economic and psychological perspective.

In economics, ambiguity refers to a choice which contains unknown probabilities. A subject's ambiguity attitude refers to how they respond to this ambiguity. They can either want to avoid it (aversion), prefer it (seeking) or be indifferent to it (neutral). In economics, decision making under ambiguous probabilities has been shown to lead to less efficient outcomes. It is generally found that subjects tend to favour choices with more certainty but less chance of winning, a phenomenon known as ambiguity aversion. Ambiguity aversion was first brought to attention by the Ellsberg urn paradox, where it was found that subjects preferred a bet with known probabilities over unknown probabilities, even when the expected outcomes are equivalent (Ellsberg, 1961). I collectively refer to how a subject responds to ambiguity as their ambiguity attitude, encompassing ambiguity aversion, ambiguity neutral, and ambiguity seeking. Ambiguity Insensitivity is another phenomenon found in ambiguous decision-making scenarios, referring to an inability to differentiate between different levels of ambiguity, tending to treat likelihoods closer to 50-50 (Dimmock et al., 2015). This results in people tending to overweight ambiguous bets at a low probability (i.e. 0.1) and underweight ambiguous bets at high probabilities (i.e. 0.9). Ambiguity aversion and intolerance to ambiguity have been shown to have an impact in real world settings such as in investment (Dimmock et al., 2016), negotiation (Van Hook & Steele, 2002; Yurtsever, 2001)and health decisions (Berger et al., 2013; Ritov & Baron, 1990). Put concretely ambiguity aversion leads to situations where an individual acts with *too much caution* when faced with ambiguity. For example, *too much caution* in the medical world can lead to risk-averse doctors overtreating patients because they seek to avoid ambiguity by overtreating patients (Berger et al., 2013). Similarly, in investments ambiguity aversion is associated with under-diversified portfolios with ambiguity averse investors more likely to invest in few assets that they 'know' rather than a larger diversified portfolio with 'unknown' assets (Dimmock et al., 2016). Using a recent example, in the case of vaccinations, it is found that ambiguity aversion is linked to vaccine hesitancy, leading to many individuals to prefer the known risk of a virus to the ambiguity surrounding vaccines (Bond & Nolan, 2011; Ritov & Baron, 1990). With COVID-19 vaccine hesitancy currently present, finding a way to improve people's ability to deal with ambiguous scenarios has immediate societal relevance.

In psychology, intolerance to ambiguity is a personality trait referring to "the tendency to perceive ambiguous situations as a source of threat" (Budner, 1962). It strictly refers to an unknown situation in the present whereas intolerance to uncertainty concerns unknown situations in the future (Grenier et al., 2005). In this paper, both economics and psychological tolerance to ambiguity are considered because previous scholarly works have found inconsistent relations between the two concepts even though by definition, they should be related, with ambiguity aversion being a part of the broader intolerance to ambiguity trait (Schröder & Freedman, 2020; Sherman, 1974; Tanaka et al., 2015).

There has been a lack of studies investigating whether ambiguity attitudes can change and, specifically, if it is possible to make individuals more tolerant to ambiguity. The majority of literature on ambiguity focuses either on measuring ambiguity or on whether the measure has external validity, such as association with stock market participation (Dimmock et al., 2016). I suggest that mindfulness meditation could be a possible intervention to help individuals be more tolerant of ambiguity. Mindfulness meditation involves performing exercises such as the deliberate focus on the breath, body scanning and reflection on thoughts to achieve mindfulness (Blanck et al., 2018). Mindfulness is a state characterised by the self-regulation of attention in order to focus on the present moment (Bishop et al., 2004). All these types of mindful meditation are characterised by a state of attention and lack of reactivity to thoughts and sensations. Recent studies have shown the promising application of mindfulness meditation as a low-cost intervention across various areas, including reducing anxiety (Baer, 2003; Chiesa & Serretti, 2009; Goyal et al., 2014; Grossman et al., 2004; Hofmann et al., 2010; Khoury et al., 2013) and in decision-making scenarios involving ethical decision making (Shapiro et al., 2012) and reducing sunk-cost bias (Hafenbrack et al., 2014) .

Evidence of the cognitive changes that occur through mindfulness meditation such as improved emotional regulation (Hill & Updegraff, 2012; Ortner et al., 2007) have promising linkages with factors that affect how an individual deals with ambiguity such as emotional response (Brand et al., 2007; Curley et al., 1986). Additionally, previous studies have found an association between intolerance to ambiguity and mindfulness measures, finding that people with higher trait mindfulness are more tolerant to ambiguity (Ie et al., 2012; Robinson, 2019).

Here, I hypothesize that the cognitive changes that occur through mindfulness meditation aid in making individuals more tolerant to ambiguity.

Hence, the focus of this paper is to see if a mindfulness meditation intervention can be applied to reduce ambiguity aversion and increase tolerance to ambiguity. This intervention is tested using a randomised controlled experiment with a treatment group being told to use the mindfulness app 'Headspace' and the control group being told to use the cognitive brain training app 'Luminosity' for a period of a week. I investigated both the psychological measure of tolerance to ambiguity and the economic measures of ambiguity attitudes and ambiguity insensitivity.

The rest of the paper is organised as follows. Section 2 covers the theoretical framework, including an overview of the concepts of mindfulness and ambiguity as well as the relationship between both. Next, section 3 lays out methodology and experimental design of the research. Section 4 covers the results and analysis. Section 5 discusses the results and concludes the paper.

Theoretical Framework

This section looks into the main literature on the effects of mindfulness and how people respond to ambiguity. It starts with an overview of studies looking into previously successful uses of mindfulness training, followed by the previous studies which have used mindfulness to improve decision-making. I then cover previous studies on decision-making under ambiguity focusing on general ambiguous scenarios before looking more specifically into ambiguity attitudes. The last part focuses on the potential mechanisms through which ambiguity attitudes and tolerance to ambiguity could be altered and the formulation of the hypotheses.

The Benefits of Mindfulness

To begin with, this part of the theoretical framework covers previously found benefits of mindfulness across different domains, with the majority of literature being found in the mental health domain. In 1979, (Jon) Kabat-Zinn was the first to bring mindfulness practice into the academic and clinical world with mindfulness-based stress reduction (MBSR), an eight-week intensive mindfulness meditation course (Kabat-Zinn, 2003). Since then, most research on the effects of mindfulness has been carried out testing the effectiveness of MBSR. There has been extensive research on the benefits of MBSR and its derivatives both in clinical and non-clinical settings. For instance, Hofmann et al. (2010) performed a meta-analysis of 39 studies focusing on mindfulness-based therapy used to treat clinical conditions such as generalised anxiety disorder and cancer. They found that mindfulness-based therapy was moderately effective in reducing anxiety and that it was an even more effective treatment for patients that specifically had an anxiety related disorder. Similar results were found in Khoury et al. (2013) who performed a meta-analysis of 209 studies focusing on MBSR use as a clinical treatment for various psychological disorders. Likewise, Goyal et al. (2014) carried out a meta-analysis of 47 randomised clinical trials with active controls additionally found similar results for reducing the symptoms of anxiety, depression and pain. Overall, these studies have shown that mindfulness in clinical settings is effective at reducing anxiety to some extent. As explained later in this paper, it is theorised that ambiguity averse individuals have an anxiety response to ambiguous scenarios (Raglan, 2014), this suggests that mindfulness could help reduce the anxiety response.

With regards to non-clinical analysis, Chiesa and Serretti (2009) performed a meta-analysis focusing on the benefits of MBSR in non-clinical populations. They found that MBSR helped reduce stress, ruminative thinking and anxiety. However, it should be noted that the studies used by Chiesa and Serretti (2009) were low-quality due to a lack of research into mindfulness-based therapies in non-clinical populations. Nonetheless, other studies have attempted at filling such a gap. Blanck et al. (2018) performed a meta-analysis to see if mindfulness as a standalone exercise helped treat anxiety and depression. This was done in order to isolate the effect of mindfulness, since studies are usually confounded by the wider therapeutical setting in which the intervention takes place. By isolating mindfulness from other therapeutic practices, they were able to show that mindfulness training was indeed beneficial in treating the symptoms of anxiety and depression in non-clinical settings. This suggest that mindfulness as a treatment can be an effective treatment in non-clinical settings.

Overall, multiple meta-analyses of studies in clinical environments have shown that mindfulness-based interventions were associated with decreases in the symptoms of depression, anxiety and stress (Baer, 2003; Chiesa & Serretti, 2009; Goyal et al., 2014; Grossman et al., 2004; Hofmann et al., 2010; Khoury et al., 2013). However, a meta-analysis by Bohlmeijer et al. (2010) and a review by Toneatto & Nguyen (2007) respectively found low and no statistically significant effect of mindfulness on anxiety and depression. While there are inconsistencies among effect size across these analyses, the vast majority show a significant effect size in reducing anxiety and stress, two factors which could play a role in determining an individual's response to ambiguity. Most of the meta-analyses state that more rigorous studies are needed to determine the exact strength of effect that mindfulness interventions have, however the initial results are promising.

These findings have additional support, with Goldin et al. (2009) finding fMRI evidence suggesting that MBSR helps alleviate the symptoms of social anxiety through changes in attentional processes, specifically the ability to redirect attention. This is corroborated by studies finding that mindfulness meditation improved performance on tasks aiming to measure attentional switching (Chambers et al., 2008) and sustained attention (Semple, 2010). Additionally, Chiesa et al. (2011) did a review of mindfulness meditation programs effects on cognitive functions. They found evidence to suggest that mindfulness training improved executive and selective attention. As such, the effects that mindfulness has on cognitive functions suggests that mindfulness could affect some of the processes by which people make decisions.

Mindfulness is also theorised to increase emotional regulation with it being found to be associated with less emotional difficulties (Hill & Updegraff, 2012). Ortner et al. (2007) found that subjects who undertook mindfulness meditation had reduced reactivity when presented with emotional pictures. This combined with mindfulness meditations' aforementioned association with reducing negative mental states, such as depression and anxiety, highlights its potential ability to help better regulate emotions. This combined with ambiguity's link with anxiety suggests that the emotional regulation from mindfulness could help reduce the emotional response to ambiguous scenarios.

Mindfulness studies are often carried out over weeks, such as with MBSR which is an eight-week program. However, mindfulness has been shown to be efficacious over a shorter period, with Tang et al. (2007) finding that 5 days of meditation practice resulted in improved attention, greater control of stress, lowered anxiety and lowered cortisol levels. They chose to do their study over a shorter period of time due to the difficulties in keeping control of longer-term mindfulness training studies. Brief mindfulness meditation has also been shown to decrease self-reported stress reactivity towards social stressors, although in this study it was also found to increase cortisol levels (Creswell et al., 2014). The increase in cortisol was hypothesised to be a result of mindfulness increasing active coping. This highlights that short-term mindfulness studies have previously been shown to be effective. Overall, previous research studying mindfulness suggests it is effective at reducing anxiety, increasing attentional control, and improving emotional regulation.

Mindfulness and Decision-making

This section looks at previous attempts to use mindfulness meditation as an intervention to improve decision-making. Mindfulness as an intervention to improve decision-making has recently picked up traction in the decision-making research field. This is because, as Alem et al. (2016) theorised, mindfulness is associated with increased executive control and could potentially work as an intervention to improve decision-making mediated through increased self-control. They tested this in the health behaviour domain, performing a randomised field study to see if 4-weeks of mindfulness training could alter health related behaviours, specifically relating to risk-taking and intertemporal decisions. They found that mindfulness training significantly decreased perceived stress and found 'indicative' evidence that participants in the treatment became more risk averse, more patient and less likely to stress eat.

A number of other studies have found mindfulness meditation to impact decision-making. (Kirk et al., 2016) found increased willingness to cooperate in the Ultimatum game. fMRI's taken during the game showed differences in regional brain activation associated with increased emotional regulation allowing subjects to be more socially cooperative. Furthermore, Shapiro et al. (2012) tested to see if MBSR therapy impacted moral reasoning and decision-making post-treatment and 2-months post-treatment. There were no statistically significant results immediately post-treatment, but two-month post-treatment showed that MBSR resulted in improved moral reasoning and ethical decision making. This was theorised to be due to the fact that ethics tend to develop overtime. It should be noted that this study lacks a randomised control group. Hafenbrack et al. (2014) tested whether mindfulness meditation could reduce sunk-cost bias. They found that subjects that undertook a 15-minute mindfulness meditation, compared to a control group, had increased resistance to the sunk-cost bias. This was linked to a reduction in negative affect associated with the sunk-cost, due to mindfulness' encouraging a focus on the present. Overall, these studies suggest that mindfulness can have a direct impact on decision-making scenarios and, in the case of Shapiro et al. (2012), showed that these changes could potentially be long lasting.

Trait Mindfulness, referring to mindfulness as a personality trait, has been shown to be associated with critical thinking through executive function, partly due to increased reflectivity (Noone et al., 2016). Executive function includes a number of processes relating to inhibition, working memory and cognitive flexibility which are required when there is a need to concentrate on a task, as opposed to doing it instinctually (Zeidan et al., 2010). Executive control can help people overcome automatic processes to engage in more critical thinking, leading to people to make more deliberate decisions. West et al. (2008) found a moderate correlation between critical thinking and the ability to avoid cognitive biases.

Teper et al. (2013) presented a model suggesting that due to mindfulness' increasing sensitivity to emotional cues it also increases executive control, as it signals a need for control. Evidence of this was suggested by Teper and Inzlicht (2013) who found using a Stroop test that the greater executive control found in meditators compared to controls was mediated by better emotional control. This is corroborated by associations found in previous studies between trait mindfulness and emotion regulation (Lyvers et al., 2014; Ostafin et al., 2014). Mindfulness meditations association with increased executive control could potentially play a role in picking up on perceptual cues when presented with a cognitive bias, using more controlled processes in decision-making scenarios. Executive function has been linked with decision-making tasks, specifically its inhibition component which was found to have a relationship with the accurate using of decision rules (Missier et al., 2010).

These studies corroborate the idea put forth by Alem et al. (2016) that mindfulness increases the ability to use controlled cognitive systems, increasing executive control. Under the dual system model of decision making, there are two systems involved in decision-making, the automatic system and the controlled system (Strack & Deutsch, 2004). It has been argued that mindfulness, through increasing self-control, can increase the usage of the controlled system, leading to more deliberate decision-making (Alem et al., 2016). Overall, the theory that mindfulness increases the ability to use controlled cognitive systems suggests that mindfulness can lead to more critical decision making.

Background on Ambiguity

Intolerance to Ambiguity and Response to Ambiguous Scenarios

In this part of the literature review I focus on what causes individuals to react in particular ways towards ambiguous scenarios, as well as associations found with tolerance to ambiguity measures. Brand et al. (2007) found evidence to suggest a role of emotion in ambiguous decision making, with subjects with selective amygdala damage (the emotional centre of the brain) performing worse in the Iowa gambling task. For instance, there has been a theorised link between anxiety and ambiguity avoidance (Raglan, 2014). When facing ambiguous scenarios, individuals who are intolerant to ambiguity tend to try and avoid the ambiguous situation, often feeling anxiety and stress when doing so. Anxious individuals have been shown to have an increased negative response towards ambiguous scenarios (Hartley & Phelps, 2012; MacLeod & Mathews, 2012; Williams et al., 1997) resulting in faster response times and overattentiveness (Cisler & Koster, 2010). This suggests that ambiguous scenarios arouse an anxiety response in individuals which could alter their decision-making process. This means that it could be possible to make an individual more tolerant to ambiguity if their anxiety or emotional response to the situation is reduced. Indeed, Raglan (2014) suggests this by arguing that mindfulness can increase people's comfort with ambiguity by increasing people's comfort with the idea of not knowing.

Budner (1962) first proposed a psychological scale to measure tolerance / intolerance to ambiguity as a personality trait, namely the intolerance to ambiguity scale. Individuals with low tolerance to ambiguity are averse to ambiguous stimuli, due to aversion to the lack of information (Furnham & Marks, 2013). Correlation between high trait mindfulness (measured using the Langer Mindfulness scale) and high tolerance to ambiguity (measured using the Intolerance to Ambiguity scale) has previously been found (Ie et al., 2012). In addition, previous studies have found correlations between tolerance to ambiguity and willingness to pay for remanufactured products (Hazen et al., 2012), life satisfaction, positive affect, reduced anxiety (Bardi et al., 2009) and increased entrepreneurial performance (Teoh & Foo, 1997).

This suggests there could be potential benefits by making an individual more tolerant to ambiguity with it being positively associated with good outcomes.

Ambiguity attitudes and ambiguity aversion

In this section, I cover background literature relating to ambiguity from the economic perspective, covering ambiguity attitudes and ambiguity insensitivity. The main method of measuring ambiguity attitudes is through the Ellsberg Urn experiment. The basic version of this experiment involves getting a subject to choose between an urn with a known proportion of red and black balls, and an unknown urn of which the proportion is not known. One of the colours is chosen as a winning colour. Theoretically without the information of how many balls are in the known urn, a subject is equally likely to win on either on choice. Dimmock et al. (2015) showed that in a representative sample there is a high tendency for subjects to choose the known urn, displaying ambiguity aversion, with roughly 70% of the population estimated to be ambiguity averse.

There is debate over whether ambiguity aversion is rational, with it violating axioms of subjective expected utility as laid out by Savage (1954). Al-Najjar & Weinstein (2009) provide an overview of the literature regarding the rationality of ambiguity attitudes. They state that efforts have been made to model ambiguity as rational, such as Gilboa & Schmeidler (1989) minimax expected utility model, by relaxing Savage's 'sure thing' principle. However, they found that by accepting Ellsberg urn choices as rational it would also require accepting sensitivity to sunk costs, updating beliefs based on tastes and aversion to information as rational.

Ambiguity aversion has been shown to have an impact in real world settings such as in investment and health decisions. An example of this is the home bias, where investors prefer to invest the majority of their portfolio domestically (known) instead of having greater international diversification (unknown). This has been shown to lead to portfolio under-diversification (Dimmock et al., 2016; French & Poterba, 1991). Ambiguity aversion has also been shown to partially explain parent's decision not to vaccinate their children (Ritov & Baron, 1990) and to effect treatment decisions by doctors (Berger et al., 2013; Han et al., 2009). In addition, ambiguity aversion theoretically increases the need for people to self-insure (Snow, 2011). Cardenas and Carpenter (2013) found a negative correlation with ambiguity aversion and well-being in Latin America, theorising that this could potentially be explained by ambiguity averse individuals being less-likely to engage with opportunities such as new technologies (Warnick et al., 2011). This highlights that reducing ambiguity aversion can lead to positive societal outcomes.

Curley et al. (1986) did a study to find the psychological causes of ambiguity aversion. They found one significant factor for ambiguity aversion, fear of negative evaluation by others. Based off of this finding, Trautmann et al. (2008) removed fear of negative evaluation in the Ellsberg Urn experiment by making preferences private information. They found that ambiguity aversion was completely removed as a result of removing fear of negative evaluation. Fear of negative evaluation is inherently linked to social anxiety with it being a part of some models of social anxiety (Gilbert, 2001; Heimberg et al., 2010). It has also been found to be negatively associated with trait mindfulness (Burton et al., 2013). In addition, ambiguity aversion has been linked to genes which have been associated with anxiety related traits (Chew et al., 2012). Overall, this strongly suggests a relationship between ambiguity aversion and an anxiety response.

Adaptions of the Ellsberg Urn experiment to include measurements at different levels of likelihood allows for the measurement of ambiguity insensitivity. Ambiguity insensitivity is considered irrational and a cognitive bias due to it reflecting a lack of understanding of an ambiguous situation (Baillon et al., 2018). This theoretically leads to suboptimal decision making, due to subjects inadequately incorporating information. It has also been found to be negative correlated with stock market participation (Dimmock et. al., 2015). To the best of my knowledge this is the only study I could find on the external validity of ambiguity insensitivity. However, due to its status as a cognitive bias, being able to reduce ambiguity insensitivity should make decision making more efficient.

Links between mindfulness and ambiguity

Previous studies have found an association between tolerance to ambiguity and mindfulness measures, finding that people with higher trait mindfulness are more tolerant to ambiguity (Ie et al., 2012; Robinson, 2019). It should be noted that these studies used different measures for measuring both mindfulness and tolerance to ambiguity, with Robinson (2019) using the Multiple Stimulus Types Ambiguity Tolerance Scale II (MSTAT-II) for tolerance to ambiguity and Mindful Attention Awareness Scale (MAAS) for Mindfulness while Ie et al. (2012) used the Intolerance of Ambiguity scale and the Langer Mindfulness Scale. This thesis contributes to the literature by testing to see if there is a causal relationship between mindfulness meditation and tolerance to ambiguity, in addition to ambiguity aversion.

Due to the tendency for ambiguous situations to cause an emotional reaction, an anxiety response and overattentiveness, I theorise that mindfulness and its previously found benefits could help reduce the negative response to ambiguous stimuli. As aforementioned, mindfulness is associated with increased emotional regulation (Hill & Updegraff, 2012) and executive control (Teper et al. 2013) suggesting that it could play a role in reducing emotional reactivity to ambiguous scenarios. I hypothesise that mindfulness meditation can make an individual more tolerant to ambiguity.

$$H1: Mindfulness\ meditation\ makes\ individuals\ more\ tolerant\ to\ ambiguity.$$

Theoretically, intolerance to ambiguity captures more areas of ambiguity than ambiguity aversion, including aversion to probabilities, complexity, novelty and insolubility (Budner, 1962). Studies have had conflicting results on the relationship between ambiguity aversion and intolerance to ambiguity, with Sherman (1974) finding some relation while both Schröder & Freedman (2020) and Tanaka et al. (2015) found no correlation between the two measures. This could potentially be due to the different measures used for ambiguity tolerance between the studies, with Sherman (1974) using the Tolerance for Ambiguity scale as laid out in Pilisuk et al. (1965), Schröder and Freedman (2020) using the Intolerance of Ambiguity Scale (Kirton, 1981) and Tanaka et al. (2015) using the discomfort with ambiguity subscale from the Need for Closure scale (Kruglanski et al., 1993). This inconclusiveness provides reasons to test for correlation between ambiguity aversion and intolerance to ambiguity leading to my second hypothesis.

$$H2: Ambiguity\ aversion\ is\ positvely\ correlated\ with\ intolerance\ to\ ambiguity.$$

Mindfulness meditation, through decreasing anxiety, has an effect on decreasing fear of negative evaluation. Hence, with fear of negative evaluation being one of the few factors found explaining ambiguity attitudes, reducing fear of negative evaluation through mindfulness could be a potential mechanism for decreasing ambiguity aversion. Additionally, mindfulness' association with increased executive control may result in a greater realisation of one's own cognitive biases. As aforementioned, ambiguity aversions status as a cognitive bias is debatable, however, ambiguity insensitivity is considered irrational and a cognitive bias (Baillon et al., 2018), hence reducing ambiguity insensitivity would technically lead to better decision making. This suggests that due to mindfulness' association with increasing executive function, emotional regulation and critical thinking that increasing a person's mindfulness could lead to a more rational choice in the Ellsberg urn experiment. Hence the above arguments lead to my third and fourth hypotheses.

$$H3: Mindfulness\ meditation\ decreases\ ambiguity\ aversion.$$

$$H4: Mindfulness\ meditation\ decreases\ ambiguity\ insensitivity.$$

Mindfulness has long been associated with increased awareness and self-reflection (Vago & David, 2012). Due to this, I hypothesise that subjects who undergo mindfulness meditation will be more likely to have more accurate self-estimations of their ambiguity attitudes over the experimental tasks.

$$H5: Mindfulness\ meditation\ leads\ subject\ to\ more\ accurately\ estimate\ their\ level\ of\ ambiguity\ aversion.$$

$$H6: Mindfulness\ meditation\ leads\ subject\ to\ more\ accurately\ estimate\ their\ level\ of\ ambiguity\ insensitivity.$$

Methods

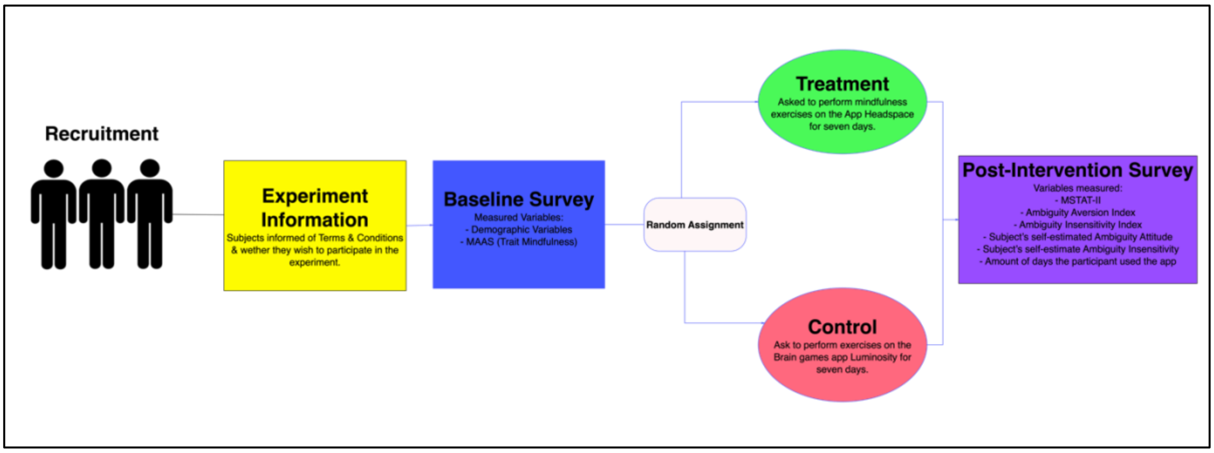
The purpose of this study is to investigate whether there is a relationship between mindfulness meditation and how an individual responds to ambiguity in decision-making scenarios. This was tested using a randomised control trial. Outcome variables assessed were tolerance to ambiguity, ambiguity aversion, ambiguity insensitivity, self-estimations of ambiguity attitude and self-estimations of ambiguity insensitivity.

Experimental Design

To test the hypothesises, a randomised control trial was performed. This involved participant filling out a baseline survey, after which they were randomly assigned to either the treatment or control group. This random assignment was done using the Qualtrics software. After a week of participants doing their assigned tasks, they were then asked to fill out a final survey to collect the dependent variables. The experimental procedure is outlined in figure 1.

Figure 1

Experimental Procedure



This intervention is short in comparison to other mindfulness'-based studies, however periods of mindfulness meditation as short as 5-days have been shown to have physiological and psychological effects (Tang et al., 2007).

To ensure anonymity over the study the subjects were provided with a randomised code in the first survey that is only known to them, which acted as an identifier in the second survey. The dependent variables make use of between subject variation to determine whether the intervention had an effect.

The Baseline Survey

At baseline a number of control variables were collected such as age, country of residence and education level. In addition, the Mindful Awareness Attention Scale (MAAS), a measure of trait mindfulness, was measured as a control to for potential differences in underlying trait mindfulness between groups. The MAAS scale is described in the materials section below.

In their representative sample, Dimmock et al. (2015) found little correlation between ambiguity attitudes and demographic variables, finding that their control variables jointly explained only 0.2-5.4% of the variation in ambiguity attitudes. They also found financial literacy to have a significant effect on ambiguity insensitivity, however this effect was low with a partial correlation of -0.097. Hence, to reduce the time burden on participants, I asked subjects if they have had tertiary education in a commerce related field, which acted as a proxy for financial literacy. This is under the assumption that students in this field are more likely to be financial literate considering finance is heavily involved in their area of study. At the end of the baseline survey participants were randomly assigned to either the treatment or the control group.

Treatment: Mindfulness Meditation through Headspace

The treatment group were told to perform at least one mindfulness meditation a day for seven days using the app ‘Headspace’ (*Headspace*, 2020). The meditations on this app generally vary from 5-20 minutes in length. Headspace was chosen due to its status as a popular meditation app, having an easy-to-follow mindfulness meditation course suitable for subjects who have not performed mindfulness meditation before. Headspace meditations tend to incorporate the following exercises: mindful breathing, body scanning and the un-evaluative viewing of thoughts. Mindful breathing exercises involve focusing your attention on your breath. Body scanning involves focusing on the sensations you feel in the different parts of your body. Un-evaluative viewing of thoughts involves noticing any thoughts that come through your mind rather than actively participating in them, before refocusing your attention on the breath.

Control: Brain Training through Lumosity

In the active control group, participants were told to perform at least one exercise daily for seven days using the cognitive brain training app ‘Luminosity’ (*Lumosity Brain Training*, 2020). The app comprises of a variety of games which are meant to improve memory and focus. This app was chosen as an active control because of its similar time requirement to the Headspace meditation app, only requiring 5-10 minutes of daily usage for reported cognitive benefits. However, benefits have only so far arisen in studies undertaken over multiple months (Hardy et al., 2015).

The Post-Intervention Survey

After the intervention occurred the participants filled out a follow up survey where the dependent variables were collected (see materials section for detailed description of variables). The subjects were also asked to self-report how many days that they used their assigned app for. Additionally, the PHLMS was collected as a manipulation check, to see if the intervention led to differences in state mindfulness after a period of mindfulness training. The activities that the participants were asked to perform in the treatment and control group are described below.

Participants

Subjects were recruited through acquaintances of the experimenters, the majority of who reside in Australia and the Netherlands. The experiment was done with Lukas Ries, sharing a participant pool for each of our experiments. The instructions and initial survey were sent out to the recruited subject pool by email. The subjects were not provided with any monetary incentive to participate. The subjects were told that they were participating in an experiment on the potential effects of smartphone app usage, being intentionally vague to avoid the experimenter demand effect. The subjects filled out both surveys and completed their assigned app usage anonymous to the experimenter. Inclusion criteria for the experiment included:

- Owning a smartphone.
- Being willing to download an app.
- Being over 18 years old.
- Not being colour-blind.

If the subjects fitted the above criteria, they were then asked to read the terms and conditions of the study. This included:

- Using the assigned app for 7-days.
- Understanding that the experimenters are not responsible for any costs if the subject forgets to cancel his/her subscription to the app after the experimental period ends.
- Filling out two self-report questionnaires, one at the beginning of the experiment and one at the end.

  If the subjects agreed to the terms and conditions they were then randomly assigned into the treatment and control groups using Qualtrics

59 People started the baseline survey of which 4 did not meet the exclusion criteria and no one was dropped for not completing the terms and conditions. This led to 55 people completing the baseline survey. Of this 55, 21 did not finish the final survey and one final survey could not be matched to a baseline survey, leaving a final sample of 33.

Materials

Baseline Variables

Mindfulness Attention Awareness Scale (MAAS). To measure trait mindfulness the 15-item MAAS questionnaire was used. Trait mindfulness refers to mindfulness as a personality trait. It is one of the most commonly used mindfulness measures and has strong internal validity, with a Cronbach's Alpha of 0.89 being found in a previous study (MacKillop & Anderson, 2007). In this experiment a Cronbach-Alpha score of 0.778 was found, displaying good internal consistency. The Cronbach-Alpha scores for the scales used in this experiment can be found in Appendix B1.

Post-Intervention Variables

Philadelphia Mindfulness Scale (PHLMS). To measure state mindfulness the PHLMS was used. State mindfulness refers to how mindful a person is over a recent period. PHLMS was designed to evaluate present moment awareness and acceptance, two of the main qualities of mindfulness. These two qualities are represented in the awareness and acceptance sub-scales within the PHLMS. The scale has also been shown to be correlated with the MAAS (Cardaciotto et al., 2008). This scale will be used as a manipulation check, with it being measured after the intervention to see if state mindfulness differed between the treatment and control. The scale and its subscale show good internal consistency, with the PHLMS scale having a Cronbach alpha of 0.852, the acceptance subscale a Cronbach alpha of 0.896 and the awareness subscale an alpha of 0.828.

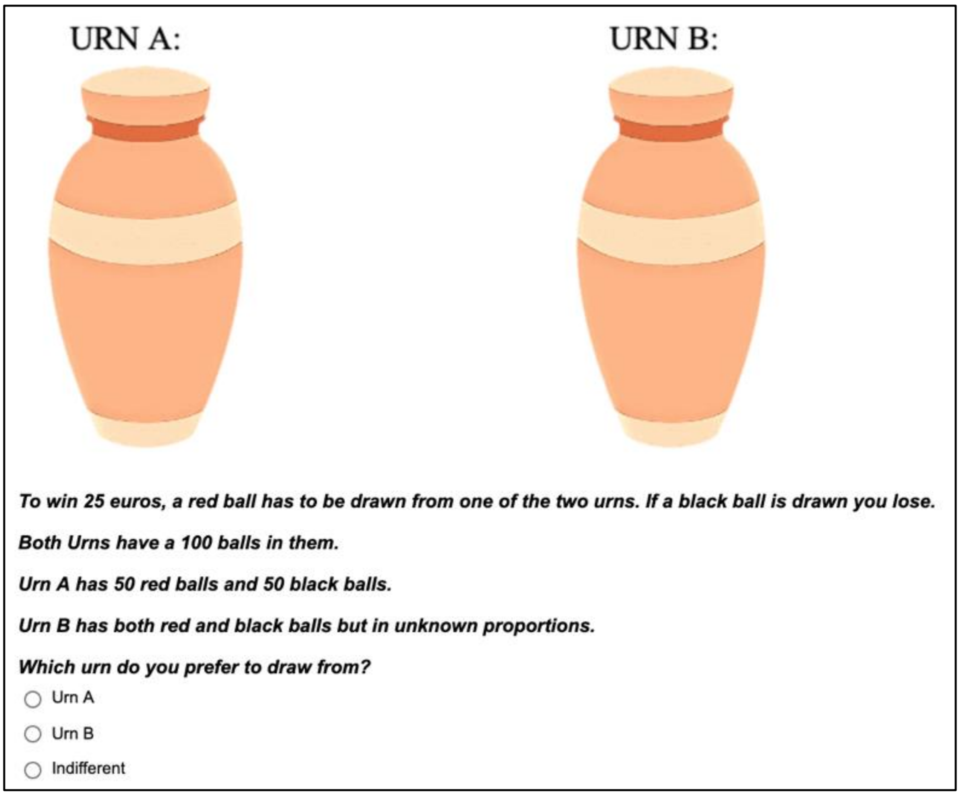
Multiple Stimulus Types Ambiguity Tolerance Scale-II (MSTAT-II). To measure tolerance for ambiguity the 13-item Multiple Stimulus Types Ambiguity Tolerance Scale-II (MSTAT-II) was used. It measures tolerance towards ambiguous "stimuli that are complex, unfamiliar and insoluble" (McLain, 2009). The scale shows good internal consistency with a Cronbach-alpha of 0.832.

Ambiguity Aversion and Ambiguity Insensitivity Indexes. To measure ambiguity aversion and ambiguity insensitivity, I will be using the same method described in Dimmock et al. (2015) with matching probabilities. From this I can construct indexes of ambiguity aversion and ambiguity insensitivity using the method designed in Abdellaoui et al. (2011). This method involves eliciting preferences for various Ellsberg urn scenarios at 3 different probability levels of success, 0.1, 0.5 & 0.9 (Dimmock et al., 2015). From these matching probabilities I can create indexes of ambiguity aversion and insensitivity as outlined in the analysis section.

Ellsberg Urn Preference elicitation: To find the matching probability for the ambiguous Ellsberg urn probability of 0.5, the subjects were presented with a choice between two urns: a known urn, which had a known proportion of red (50) and black balls (50), and an unknown urn, which had an unknown proportion of red and black balls. The subject choice was hypothetical, and they were asked to think as if drawing a red ball would lead them to win 50 euros. Figure 2 illustrates the choice that was presented to subjects.

Figure 2

Ellsberg Urn Preference Elicitation Question (50% Probability level of success)



The unknown urn represents a source of ambiguity, since the proportions are not known, while the known urn represents a source of risk, since the proportions are known. An ambiguity neutral subject would assign a subjective probability of 50-50 to the unknown urn. If the subject chooses the known urn over the unknown urn, then it is known that they have assigned a subjective probability to the unknown urn less than 50%, portraying ambiguity aversion. If this occurs, additional questions will be asked following a bisectional approach, with the known urn's probability of success being made more or less attractive based on the subjects' previous responses. If the subject previously chose the known urn, for the next choice I would decrease the known urns probability of winning to make the unknown urn more attractive. The probability at which the subject becomes indifferent is the matching probability for the Ellsberg probability of 0.5.

To measure the ambiguous Ellsberg urn probability of 0.1, I presented the participants with an unknown urn with 100 balls of 10 different colours in unknown proportions and a known urn with 100 balls of 10 different colours in equal proportions (10%). An example of the question asked can be found in appendix A1. I then presented another hypothetical choice to the subjects, asking them to choose an urn to win a hypothetical 50 euros if a red ball is drawn from that urn. Depending on the subject's choice I made the known urn more or less attractive till the subject becomes indifferent in order to find their matching probability for Ellsberg urn probability of 0.1.

To measure the ambiguous Ellsberg urn probability of 0.9 I performed a similar task as measuring the probability of 0.1, however instead of the red ball winning it is now the losing colour, inversing the probability of success. An example of the question asked can be found in appendix A2.

Additionally, I performed an inconsistency check using the subjects matching probability for Ellsberg probability of 0.5. This involved changing the probability for the known box to the subjects matching probability plus 10% for the first check question and minus 10% for the second check question. In line with Dimmock et al. (2016) a subject's response is considered inconsistent if he/she prefers the unknown box in the first check question or if he/she prefers the known box in the second check question.

Constructing the Ambiguity Aversion and Ambiguity Insensitivity Indexes: For each of the probabilities I elicited preferences for (0.1, 0.5 & 0.9), a local ambiguity index will be created from the formula below, where p is the objective probability (0.1, 0.5 or 0.9) and m(p) is the matching probability, the subjective probability of success assigned by participants given the ambiguity of the choice. The matching probability is elicited through the preference elicitation method stated before.

$$Local\ Ambiguity\ Index_p = p - m(p)$$

To create the global indexes used in Abdellaoui et al. (2011) a linear line of best fit on the open interval (0, 1) using the matching probabilities is estimated. This is calculated per participant, graphing their matching probabilities for the probabilities of 0.1, 0.5 & 0.9 on the open interval. From here a linear line of best fit is calculated, with c representing the intercept and s the slope of this line of best-fit.

$$m(p) = c + sp$$

Having the slope and intercept I can calculate the ambiguity insensitivity index and ambiguity aversion index as done in Abdellaoui et al. (2011) using the following equations:

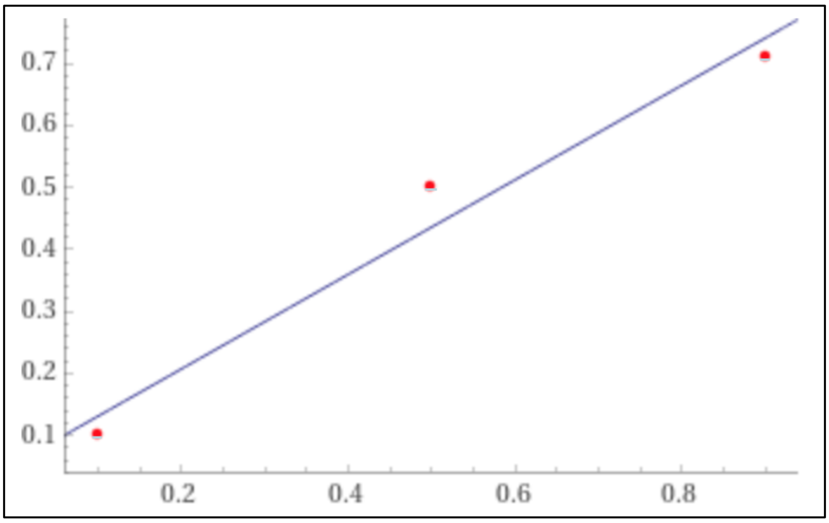
$$ambiguity\ insensitivity\ index = 1 - s$$
$$ambiguity\ aversion\ index = 1 - s - 2c$$

For the ambiguity aversion index, a value less than zero corresponds to ambiguity seeking, a value of zero implying being ambiguity neutral and a value greater than zero implying ambiguity aversion. The further from zero the more ambiguity seeking or averse a person is (depending on direction). For ambiguity insensitivity, any value deviating from zero implies ambiguity insensitivity with being further from zero implying stronger insensitivity.

Figure 3 shows an example of the process of calculating the line of best fit from the matching probabilities and subsequently calculating the index values from the slope and intercept of the line.

Figure 3

Calculating Ambiguity Indexes from matching probabilities



Note. this subject displayed the following matching probabilities M(0.5) = 0.5, M(0.1) = (0.1), M(0.9) = (0.71). Plotting these points, the line of linear best fit was calculated as 0.7625x + 0.0554167. From this we can calculate the ambiguity insensitivity index, 1 – 0.7625 = 0.2375 and the ambiguity aversion index, 1 – 0.7625 – 2*0.0554167 = 0.1267.

Awareness of Ambiguity Aversion & Insensitivity: I will provide the subjects with definitions of ambiguity aversion and ambiguity insensitivity. They will then be asked what they thought their ambiguity attitude was in regard to how they answered the previous questions. This will be answered on a 20-point scale from ambiguity seeking (-10) to ambiguity averse (10). I will also ask how ambiguity insensitive the subjects think they are on a 10-point scale from displaying no ambiguity insensitivity (0) to being completely insensitive to ambiguity (10). Appendix A3 shows an example of how the questions were presented to subjects. These measures will be referred to as self-estimated ambiguity aversion and self-estimated ambiguity insensitivity.

Analysis

Firstly, using parametric or non-parametric tests, I performed a normality check on both my control and outcome variables to see if I had to compare difference between the treatment and control group. This was done using both skewness-kurtosis tests and Shapiro-wilk tests. After this I calculated the Cronbach alpha of my scales to check that they were internally consistent.

I then performed a manipulation check using my PHLMS variable to see if there was a difference in state mindfulness between treatment and control, acting as an indicator that the mindfulness meditation had an effect. This was done using a t-test. Due to the t-test having the additional assumption of equal variances, a variance ratio test was performed whenever a t-test was used to check this assumption.

After this I performed randomisation tests to see if there were any difference in control variables between the treatment and control. For this, t-tests were used for normally distributed variables such as age, Fischer exact tests for binary variable and the one nominal variable (Country of Residence). The Fischer exact tests were used over the chi-squared test due to the small sample size of this experiment. Mann-Whitney tests were used for ordinal variables such as education and mindfulness frequency. If a control variable was found to be significantly different between treatment and control, it will then be tested against the outcome variables to see if there is a relationship between the control variable and the outcome variables. I also checked if being assigned to treatment and control had a statistically significant effect on whether a subject was likely to finish the whole experiment using Fischer exact tests.

After these checks, I performed the hypothesis tests. For hypothesis 1, 3 & 4, If the outcome variables were shown to be normally distributed, I performed a t-test to see if there was a difference between treatment and control groups. If they failed to meet the assumptions for normality, I performed a Mann-Whitney test, treating the outcome variables as ordinal.

The randomisation check for mindfulness experience and mindfulness frequency ended up showing that there were different distributions of subject's mindfulness experience and mindfulness frequency between the treatment and control. Due to this, I additionally performed a two-way ANOVA test for hypothesis 1 using MSTAT-II as the outcome variable and treatment group and mindfulness experience as the explanatory variables. I did this as opposed to a three-way ANOVA test due to the mindfulness experience and mindfulness frequency variables both being related, with mindfulness experience measuring if a participant has previously undertaken mindfulness meditation (yes/no) and mindfulness frequency measuring how often they had meditated. As a result of this I decided to only use only one as a control. I chose to use mindfulness experience as the control, due to it having more observations per category, with some mindfulness frequency categories only having as little as 2 observations. I again did this for hypothesis 3 & 4, performing ordered logit regression instead because the ambiguity aversion index and ambiguity insensitivity index were both not normally distributed.

I also checked the proportions of subjects in each treatment who displayed ambiguity aversion, ambiguity seeking and ambiguity neutrality at the Ellsberg urn probabilities of 0.1, 0.5 & 0.9. This was done by looking at the local ambiguity index for each of the probabilities, with a subject displaying ambiguity aversion if that index is positive, ambiguity neutrality if it is zero and ambiguity seeking if it is negative.

To test hypothesis 2, I used spearman correlation since the ambiguity aversion index was not normally distributed. Due to the assumption of monotonic relation for spearman correlation, I also checked the scatter plot of MSTAT-II & the ambiguity aversion index to check the direction of the relationship.

For hypothesis 5 & 6, I performed correlation tests between self-estimated ambiguity aversion (or self-estimated ambiguity insensitivity) and the global ambiguity aversion index (or ambiguity insensitivity index) for the treatment and control groups separately. I then performed a Fischer's Z transformation to see if the difference in correlation between the treatment and control group is statistically significant. Due to the use of spearman's correlations, I performed a variation of the Fischer Z transformation as found in Sheskin (2003). This is under the assumption that the sample sizes are greater or equal to 10 and the population spearman rho is less than 0.9.

Results

Participants

54 people filled out the initial survey for selection into the experiment. Of the 54 people who completed the initial survey, all participants met the inclusion criteria, while 4 participants did not agree to the terms and conditions. Of the 50 people that remained, 24 were randomly assigned to the treatment group while the other 30 were assigned to the control group. The unequal division was due to the randomisation process. After the 7-days of treatment, 34 people finished the follow-up survey. One observation had to be dropped due to being unable to match the follow-up survey code with the baseline survey code. This left 33 observations of which 16 were in the treatment group and 17 in the control group.

Descriptive Statistics

Table 1 presents summary statistics of the demographic and control variables collected before the intervention. Note, only the statistics of those who finished the intervention are shown. Panel 1 reports the summary statistics for all participants, panel 2 for participants in the control group, panel 3 for participants in the treatment group and panel 4 reports if there was a statistically significant difference between the treatment and control groups for the demographic variable.

Table 1
Baseline Characteristics

Variables	All (n=33) (1)	Control (n=17) (2)	Treatment (n=16) (3)	Difference (4)
Age	23.121	23.24	23	0.24†††
	(2.22)	(2.25)	(2.25)	
Male	63.64%	58.82%	68.75%	9.93pp††
Commerce Degree	51.52%	58.82%	43.75%	15.07pp††
MAAS	3.598	3.592	3.604	0.012†
	(0.64)	(0.78)	(0.47)	
Occupation				
Student	66.67%	64.71%	68.75%	4.04pp††
Full-time / Other	33.33%	35.29%	31.25%	17.5pp††
Education				
Primary	3.03%	0%	6.25%	6.25pp†
Secondary	15.15%	23.53%	6.25%	17.28pp†
Undergrad	60.61%	52.94%	68.75%	15.81pp†
Postgrad	21.21%	23.53%	18.75%	4.78pp†
Country				
Australia	39.39%	47.06%	31.25%	15.81pp††
Netherlands	39.39%	35.29%	43.75%	8.46pp††
Other	21.12%	17.64%	25%	7.36pp††
Mindfulness Experience	63.64%	47.06%	81.25%	34.19pp***††
Mindfulness Frequency				
Never	36.36%	52.94%	18.75%	34.19pp*†
Once a month	24.24%	17.65%	31.25%	13.6pp*†
Once a week	9.09%	5.88%	12.50%	6.62pp*†
2-3x per week	3.03%	0%	6.25%	6.25pp*†
4-6x per week	18.18%	17.65%	18.75%	1.1pp*†
Daily	9.09%	5.88%	12.50%	6.62pp*†

*** p<0.01, ** p<0.05, * p<0.1
† Mann-Whitney U Test †† Fischer Exact Test, ††† T-Test,

Note. significance under categorical variables refers to difference in distributions between the treatment and control, not a significant percentage point difference in the individual catergory.

The average age of participants was 23 in both the treatment and control. The majority of participants were students (66.67%) and 81.82% of subjects were educated to at least the undergraduate level. The majority of responses came from either Australia (39.39%) or Netherlands (39.39%) with the remainder coming from a variety of different countries around the world. 63.64% of the subject pool have had previous experience with a mindfulness activity such as meditation or yoga. 39.39% of the subject pool engage in a mindfulness activity at least once a week. 63.64% of participants were male and 51.52% had previously engaged in a Commerce/Business related degree.

Checks

Randomisation check

Randomisation checks were performed to ensure that potential confounding variables were evenly distributed between the treatment and control. T-tests were used to see if the average age was significantly different between groups while Fischer exact tests were used to test for differences in the categorical variables. Due to the MAAS measurement's failure to meet normality assumptions, a Mann Whitney U test was used to see if the sum of ranks were different between groups. Additionally, the Mann Whitney U test was used for the ordinal variables.

Out of the control variables, Fischer exact tests showed statistically significant difference in distributions between treatment and control for previous experience with mindfulness meditation (p-value < 0.1) and a Mann Whitney U test showed that the treatment group participants tended to have higher frequency of meditation, being statistically significant at a 10% significance level (p = 0.097). The other control variables were not deemed statistically significant at a 10% significance level using their respective tests.

These variables (mindfulness experience & mindfulness frequency) were checked against the outcome variables to see if they had associations. For the mindfulness experience variable, I compared it against the normally distributed outcome variable (MSTAT-II) using a T-test and against the non-normally distributed variables (ambiguity insensitivity index & ambiguity aversion index) using Mann-Whitney tests. For the mindfulness frequency variable, (since it is composed of multiple categories) Kruskal-Wallis tests (for non-normal outcome variables) and ANOVA (for normal outcome variables) tests were used to see if there was a relationship between mindfulness frequency and the outcome variables.

For the mindfulness experience variable, a Mann-Whitney test found a statistically significant difference in subjects estimated ambiguity aversion with those who had previous experience meditating tending to estimate that they were ambiguity seeking (mean = -1.33) compared to those with no experience meditating, who tended to estimate that they were ambiguity averse (mean = 2.583) at a 5% significance level (p = 0.037). The other outcome variables had no significant relationship with mindfulness experience at a 10% significance level using their respective tests.

For mindfulness frequency, an ANOVA test found that subjects estimated ambiguity aversion and mindfulness frequency were not independent at a 1% significance level ($p = 0.01$). With mindfulness frequency being associated with increased estimated ambiguity seeking. The other outcome variables had no significant relationship with mindfulness frequency at a 10% significance level using their respective tests.

Normality Check

Normality tests were performed on the outcome variables and the two mindfulness indexes using the Shapiro-Wilk Test and the skewness-kurtosis test. The table for the normality checks can be found in appendix B2. Both the ambiguity insensitivity index ($p < 0.01$) and the ambiguity aversion index ($p < 0.01$) were not deemed to be normally distributed using the Shapiro-Wilk Test. This was also the case for all local ambiguity indexes ($p < 0.01$) and the MAAS ($p < 0.01$). As a result, non-parametric tests such as the Mann Whitney U test were used in the analysis for these variables. Additionally, the MSTAT-II scale ($p = 0.04$) and the ambiguity insensitivity index ($p = 0.02$) experienced kurtosis. The ambiguity aversion index ($p = 0.022$) and the MAAS index ($p < 0.01$) experienced skewness.

Consistency check

Two check questions were included to see if subject's ambiguity attitudes were consistent. The first question asked for the subjects Urn preference using a probability of success derived from the subjects matching probability for the Ellsberg Urn probability of 0.5 plus 10%. The second question asked for the subject's preference using the subjects matching probability for the Ellsberg Urn probability of 0.5 minus 10%. 12.1% of subjects displayed inconsistent response to check question 1 and 0% of subjects displayed inconsistent response to check question 2. 9.1% displayed indifference in the first check question while 15.2% displayed indifference in the second check question. Subjects who displayed inconsistent preferences in the Ellsberg Urn questions were dropped as a robustness check later on in the analysis.

Manipulation check

As a manipulation check, the subjects state mindfulness was measured to see if there was a significant difference between the treatment and control. If mindfulness meditation had an effect, then it should be reflected in a higher state mindfulness score compared to the control group. The control group had a higher average PHLMS score ($M = 3.418$, $SD = 0.154$) than the treatment group ($M = 3.231$, $SD = 0.126$), going against expectation. A two-sampled t-test was used to see if there was a significant difference in PHLMS scores between groups. The test indicated no significant difference between the treatment and control groups PHLMS scores (t= 0.93, p=0.36). Hence there is no evidence to suggest that the mindfulness meditation intervention had the desired effect.

Outcome Variables & Hypotheses testing

Outcome Variable Correlation

Table 2:
Spearman Correlations for Outcome Variables

Correlations	1.	2.	3.	4.	5.	6.
1. MAAS	-					
2. PHLMS	-0.1612	-				
3. MSTAT-II	0.4605***	-0.4369***	-			
4. Ambiguity Aversion Index	0.2420	-0.1698	0.1248	-		
5. Ambiguity Insensitivity Index	0.1279	-0.1649	0.0084	0.3696**	-	
6. Self-estimated Ambiguity Attitude	-0.1676	0.0310	-0.2017	0.1056	0.1873	-
7. Self-estimated Ambiguity Insensitivity	0.1903	0.0182	0.3326*	-0.1547	-0.0071	0.1528

*** p<0.01, ** p<0.05, * p<0.1
N = 33

Note. MAAS = Mindful Attention Awareness Scale

PHLMS = Philadelphia Mindfulness Scale

MSTAT-II =Multiple Stimulus Types Ambiguity Tolerance Scale-II

The results of the Spearman correlation (as seen in Table 2) indicate that there is a significant positive association between MSTAT-II and the MAAS Index (r = 0.4605, p <0.01). There is also a significant negative correlation between PHLMS and MSTAT-II (r = -0.4369, p <0.01). There was no significant correlation between the two mindfulness measures, MAAS and PHLMS (r = -0.1612, pvalue <0.1). The ambiguity aversion index had a significant positive correlation with the ambiguity insensitivity index (r = 0.4038, p <0.05). This is higher than the 0.22 correlation found between the variables in Dimmock et al. (2015). There was also a significant correlation found between MSTAT-II and self-estimated ambiguity insensitivity (r = 0.3326, pvalue <0.1).

Main results

Hypothesis 1: Mindfulness meditation makes individuals more tolerant to ambiguity. To test hypothesis 1, I compared the treatment and controls MSTAT-II scores to see if they were significantly different. The results of the test and summary statistics for

MSTAT-II can be seen in table 3. An independent t-test indicated that there was no significant difference between the treatment (mean = 3.447) and control (mean = 3.434) groups MSTAT-II scores (t = -0.064, p = 0.95). Hence there is no evidence to suggest that mindfulness meditation can increase tolerance to ambiguity.

Table 3:

Summary Statistics & Independent t-test– Normally Distributed Variables

Variables	Control (17)		Treatment (16)		Difference	*t*(31)	*p*
	Mean	SD	Mean	SD			
MSTAT-II	3.434	.591	3.447	.558	.013	-0.064	0.475
Self-Estimated Ambiguity Attitude	0.765	5.203	-0.625	5.390	1.390	0.754	0.228
Self-Estimated Ambiguity Insensitivity	6.176	2.298	5.875	1.893	0.301	0.410	0.342

*** p<0.01, ** p<0.05, * p<0.1

Due to subject’s mindfulness experience and mindfulness frequency not being randomly distributed between treatment and control, I also performed a two-way ANOVA test using MSTAT-II as the dependent variable with treatment and mindfulness experience as the factors. The results of the ANOVA test can be seen in table 4. The ANOVA test indicated that there was no significant difference in MSTAT-II scores between treatment and control (p = 0.881) at 10% significance level. This confirms the results of the independent t-test. Additionally, both mindfulness experience (p = 0.981) and the interaction term (p = 0.755) were insignificant at a 10% significance level.

Table 4:

Two-way ANOVA Analysis using MSTAT-II as criterion (ft. Mindfulness Experience Control)

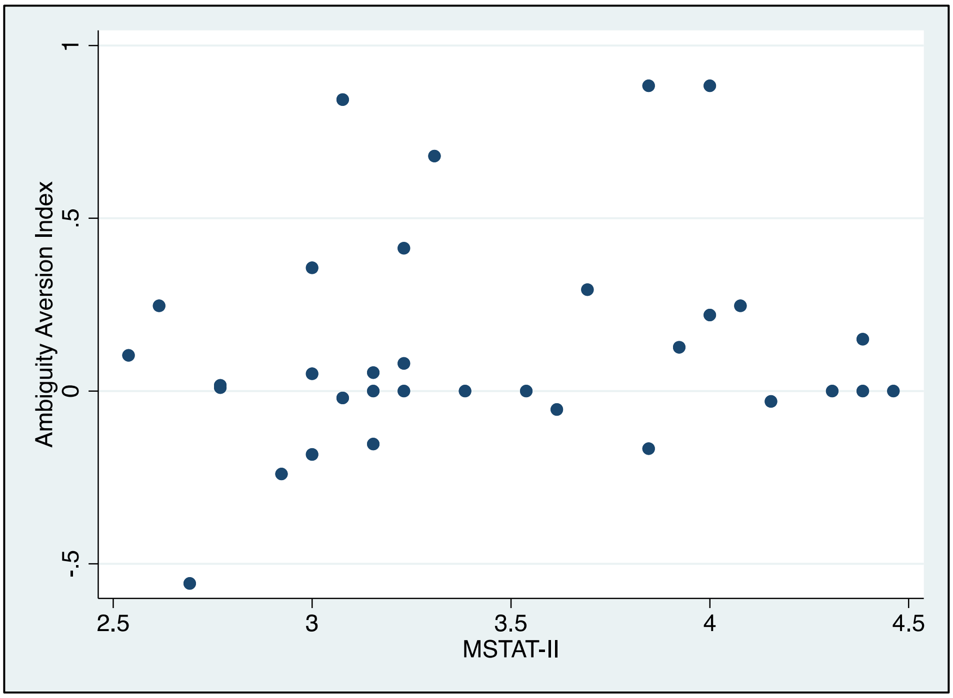
Predictor	Partial Sum of Squares	*df*	Mean Square	*F*	*p*	η^2	η^2 90% CI
Intercept	10.214	29	.352				
Treatment	.008	1	.008	0.02	0.881	.001	[. , .092]
Mindfulness Experience	.000	1	.000	0.00	0.981	.000	[. , .]
Treatment x Mindfulness Experience	.035	1	.035	0.10	0.755	.003	[. , .132]

*** p<0.01, ** p<0.05, * p<0.1

Hypothesis 2: Ambiguity aversion is positively correlated with intolerance to ambiguity. To test my second hypothesis, I looked at the correlation between the ambiguity aversion index and MSTAT-II scores. The scatterplot of each individuals Ambiguity Aversion Index and MSTAT-II score can be seen in figure 4. Results of the Spearman correlation indicated that there was an insignificant positive relationship between ambiguity aversion and intolerance to ambiguity (R = 0.122, p = .497). This suggests that tolerance to ambiguity and ambiguity aversion are separate and distinct measurements of ambiguity.

Figure 4

Scatterplot of Ambiguity Aversion Index & MSTAT-II score



Note: Each dot represents an individual subjects observed scores.

Hypothesis 3: Mindfulness meditation decreases ambiguity aversion.

Breakdown of Subjects Ambiguity Attitudes: Table 5 shows proportions of subjects in each treatment who displayed ambiguity aversion, ambiguity seeking and ambiguity neutrality at the Ellsberg urn probabilities of 0.1, 0.5 & 0.9. The control group had a smaller proportion showing ambiguity aversion and a higher proportion showing ambiguity neutrality across all Ellsberg Urn probabilities, the opposite of what was expected. Overall the distribution of ambiguity attitudes are similar to previous studies finding that subjects tend to be ambiguity seeking at low probabilities of success and ambiguity averse at 50-50 and higher probabilities of success (Dimmock et al., 2015).

Table 5:

Ambiguity attitudes at different probability levels

	Ambiguity Attitude	Ellsberg Urn Probability of 0.1	Ellsberg Urn Probability of 0.5	Ellsberg Urn Probability of 0.9
	Ambiguity Averse	37.5%	62.5%	62.5%
Treatment	Ambiguity Neutral	25.0%	18.75%	12.5%
	Ambiguity Seeking	37.5%	18.75%	25.0%
	Ambiguity Averse	23.5%	41.2%	58.8%
Control	Ambiguity Neutral	29.4%	41.2%	29.4%
	Ambiguity Seeking	47.1%	17.6%	11.8%
	Ambiguity Averse	30.3%	51.5%	60.6%
Total	Ambiguity Neutral	27.3%	30.3%	21.2%
	Ambiguity Seeking	42.4%	18.2%	18.2%

Looking at the subject's local ambiguity indexes in Table 6, the median ambiguity index for the local probability of 0.1 in both the treatment and the control is 0, implying ambiguity neutrality. The median ambiguity index for the local probability of 0.5 in the control was 0, implying ambiguity neutrality, and in the treatment group it was 1.5, implying slight ambiguity aversion. The median ambiguity index for the local probability of 0.9 in the control was 19 and in the treatment was 9.5, both implying ambiguity aversion. As seen in table 6, none of the local ambiguity attitude indexes were significantly different between the treatment and control at a 10% significance level, using a Mann Whitney U Test.

Testing differences in Ambiguity Attitudes: To test my third hypothesis, I compared the overall ambiguity aversion index between the treatment and control group. The summary statistics and if the difference between treatment and control was significant (using Mann-Whitney U tests) can be found in table 6 and the specific results of the Mann-Whitney U test can be found in Appendix C. A Mann-Whitney U test indicated that there was no statistically significant difference between the treatment and controls ambiguity aversion index ($p = 0.538$) at a 10% significance level. The treatment group did have a slightly higher median level of ambiguity aversion (mdn = 0.065) compared to the control group (mdn = 0), while it was expected that the treatment group would have a lower median level of ambiguity aversion.

Table 6:

Summary Statistics & Difference Between Treatment and Control – Non-Normally Distributed Variables

Demographic	Control (17)			Treatment (16)			Difference
	Median	Min	Max	Median	Min	Max	
Ambiguity Aversion Index	0	-.24	.843	.065	-.557	.883	.065
Ambiguity Insensitivity Index	.2625	0	1	.2375	-.1	1	0.025
$AA_{0.1}$	0	-40	3	0	-65	9	0
$AA_{0.5}$	0	-22	43.5	1.5	-31.5	43.5	1.5
$AA_{0.9}$	19	-9	80	9.5	-9	80	9.5

*** p<0.01, ** p<0.05, * p<0.1

Note. Significance of difference between Treatment and Control was calculated using a Mann-Whitney U Test

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Due to subject's mindfulness experience and mindfulness frequency not being randomly distributed between treatment and control, I also performed an ordered logit with the ambiguity aversion index as the independent variable, mindfulness experience as a control variable and being in the treatment group as an explanatory dummy variable. The results of this test can be seen in table 7. Both the coefficient of the treatment dummy (p = 0.652) and for mindfulness experience (p = 0.697) were insignificant at a 10% significance level.

Table 7

Results – Ambiguity Aversion Ologit (ft. Mindfulness Experience)

Variables	Coefficient	SE	Odds Ratio
Treatment	.295	.653	1.343
Mindfulness Experience	.269	.692	1.309

*** p<0.01, ** p<0.05, * p<0.1

Hypothesis 4: Mindfulness meditation decreases ambiguity insensitivity. To test my fourth hypothesis, I compared the ambiguity insensitivity index between the treatment and control group. The summary statistics and if the difference between treatment and control was significant (using Mann-Whitney U tests) can be found in table 6 and the specific results of the Mann-Whitney U test can be found in Appendix C. A Mann-Whitney U test indicated that there was no statistically significant difference in the ambiguity insensitivity index between the treatment and control group (p = 0.4799) at a 10% significance level. The treatment group did have a lower median (mdn = 0.2375) compared to the control group (0.2625) which was the expected direction of effect.

Again, due to subject's mindfulness experience and mindfulness frequency not being randomly distributed between treatment and control, I performed an ordered logit with ambiguity insensitivity index as the independent variable, being in treatment as a dummy variable and mindfulness experience as a control. The results of this test can be seen in table 8. Both the coefficient of the treatment dummy (p = 0.341) and for mindfulness experience (p = 0.436) were insignificant at a 10% significance level.

Table 8

Results – Ambiguity Insensitivity Ologit (ft. Mindfulness Experience)

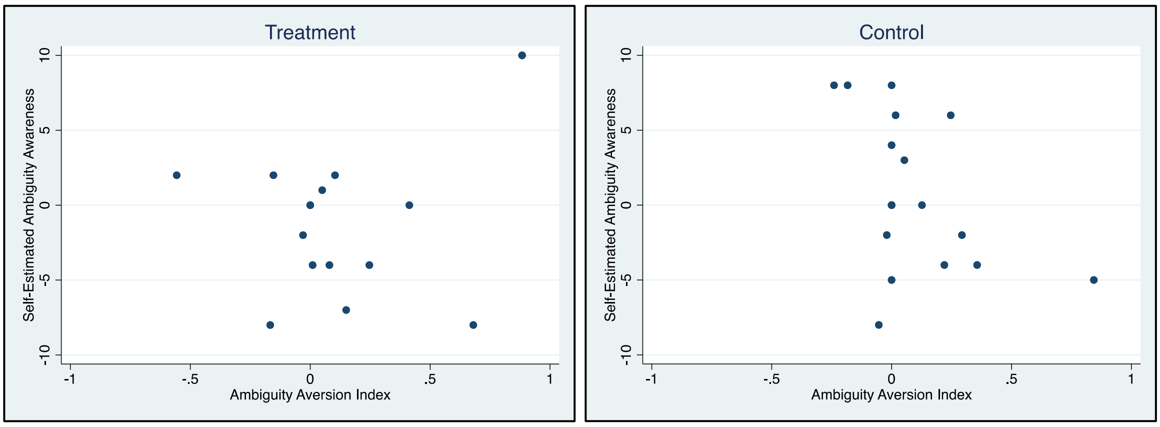
Variables	Coefficient	SE	Odds Ratio
Treatment	.630	.661	1.877
Mindfulness Experience	-.537	.690	.584

*** p<0.01, ** p<0.05, * p<0.1

Hypothesis 5: Mindfulness meditation leads subjects to more accurately estimate their level of ambiguity aversion. For my fifth hypothesis, I compared Spearman correlation's between treatment and control between the ambiguity aversion index and the subjects self-estimated ambiguity attitudes. The descriptive statistics of these variables can be seen in table 3. A positive correlation would indicate a more accurate evaluation of how a subject performed during the preference elicitation part of the survey. Figure 5 shows the scatterplot of each individuals self-estimated ambiguity attitude compared to their elicited ambiguity index. Each dot represents a subject's observed scores. As seen in the scatterplots, there seems to be little accuracy in both the treatment and controls predictions.

Figure 5

Scatterplot of Elicited & Self-Estimated Ambiguity Attitudes for both Treatment & Control



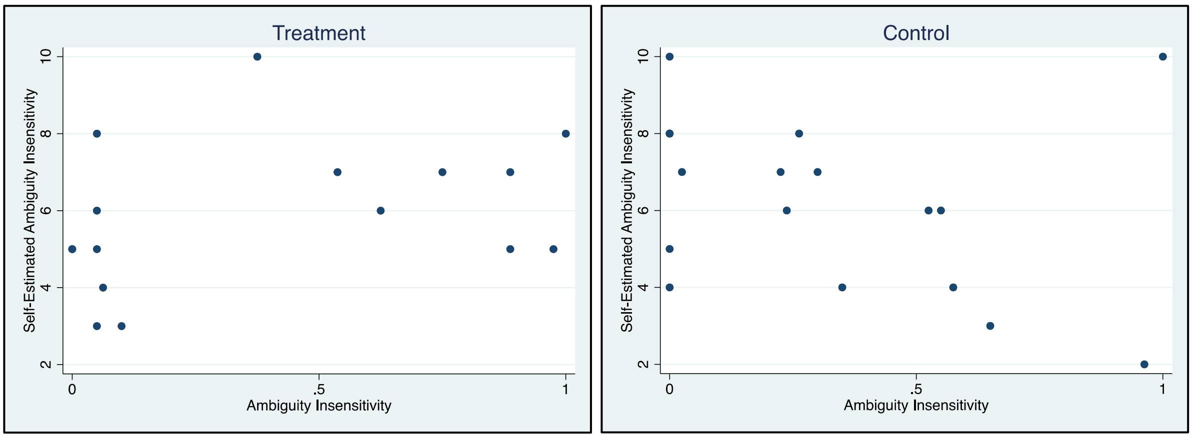
Note. Each dot corresponds to an individual observations observed scores.

In the treatment group, the correlation between ambiguity aversion index and self-estimated ambiguity attitudes was not significant (Rho = 0.1056, p = 0.697). In the control group, the correlation between ambiguity aversion index and self-estimated ambiguity attitudes was also not significant (Rho = 0.3425, p = 0.178). Hence, this suggests that there is no significant relationship between the subjects self-estimated ambiguity attitudes let alone a difference between the treatment and control.

Hypothesis 6: Mindfulness meditation leads subjects to more accurately estimate their level of ambiguity insensitivity. For my sixth hypothesis, I compared Spearman correlation's between treatment and control between the ambiguity insensitivity index and the subjects self-estimated ambiguity insensitivity. The descriptive statistics of these variables can be seen in table 3. A positive correlation would indicate more accurate evaluation of how a subject performed during the preference elicitation part of the survey. Figure 6 shows the scatterplot of each individuals self-estimated ambiguity insensitivity compared to their elicited ambiguity insensitivity index. The scatterplot shows an apparent directional effect, although this directional effect is different for both treatment and control. The treatment group had a positive directional effect, suggesting more accurate estimations while the control group had a negative directional effect, suggesting less accurate estimations.

Figure 6

Scatterplots of Elicited & Self-Estimated Ambiguity Insensitivity for both Treatment & Control



Note: Each dot corresponds to an individual observations observed scores.

In the treatment group, the correlation between ambiguity insensitivity index and the subject's self-estimated ambiguity insensitivity was positive and insignificant (R = 0.3460, p= 0.1893). In the control group, the correlation between ambiguity insensitivity index and the subject's self-estimated ambiguity insensitivity was negative and insignificant (R = -0.3611, p =0.154). It is interesting to note that the sign of the correlation coefficients indicated that participants in the treatment group were somewhat more accurate in estimating their actual ambiguity insensitivity (positive rho) than participants in the control group (negative rho). Due to the large difference in correlations between the treatment and control, I performed a Fischer's Z Transformation to compare the difference between the Rho's of the treatment and control to allow for the comparison of differences in correlation. The difference was statistically significant at a 5% significance level (z = -1.919, p = 0.028). This suggests differences between the treatment and controls estimations of their own level of ambiguity insensitivity, with the treatment group having closer estimation to their actual performance. However, due to the individual correlations being insignificant the significance of the difference should be interpreted carefully.

Robustness tests

I performed a number of robustness checks by dropping various observations based on three different criteria: Inconsistent preferences, number of days of meditation completed and previous experience with meditation. Appendix D shows the summary statistics for the various robustness checks.

For my first check, I dropped 4 responses who answered the check questions inconsistently. This was in order to get rid of potentially inaccurate observations. This led to there being 13 observations in the treatment group and 16 in the control group. The results of the tests for this check can be seen in Appendix D1, D2 & D3. None of the outcome variables, except the difference in correlation between self-estimated ambiguity insensitivity and elicited ambiguity insensitivity, changed in significance, with them all remaining insignificant. For the difference between the treatment and control group correlation's between estimated ambiguity insensitivity and elicited ambiguity insensitivity, the difference became less significant, with the difference in correlations moving from being significant at a 5% level (at base analysis) to being significant at a 10% significance level ($z = -1.366$, $p = 0.086$) in this robustness check. It should be noted that the individual correlations between self-estimated ambiguity insensitivity and elicited ambiguity insensitivity remained insignificant at a 10% significance level for both treatment and control.

For my second check, I dropped 12 observations who reported that they did not finish all 7-days of the intervention. This was done in order to see if there was an effect on the subjects who followed the exact specifications of the experiment's instructions. This led to there being 7 observations in the treatment group and 14 in the control group. The results of the tests for this check can be seen in Appendix D4, D5 & D6. The difference between ambiguity insensitivity indexes between treatment and control was significant at a 10% significance level ($p = 0.091$). The treatment had a higher median (mdn = 0.75) than the control group (mdn = 0.25) indicating that the treatment made subjects more ambiguity insensitive. The results should be viewed cautiously due to the low number of subjects left after dropping observations for this robustness check.

The rest of the results did not change in level of significance except for the difference between the treatment and control's correlations between estimated ambiguity insensitivity and elicited ambiguity insensitivity ($z = -1.155$, $p = 0.124$). This difference moved out of significance becoming insignificant at a 10% significance level in this robustness check. However, for this robustness check, the assumptions of the Fischer Z transformation for Spearman Correlations does not hold, with the treatment sample size being under 10 observations ($n = 7$). It should be noted that the individual correlations between self-estimated ambiguity insensitivity and elicited ambiguity insensitivity remained insignificant at a 10% significance level for both treatment and control.

For my third check I dropped observations who had previous experience with meditation. This was done in order to see if there was any effect on a population with no previous mindfulness experience, since those with previous experience may have already potentially received some benefits from mindfulness meditation. This turned out to disproportionately affect the treatment group which only had three observations. Hence, since the observations from this were low, I ran my last check dropping the 13 subjects who meditated at least weekly. This ensured that everyone was at least experiencing an increase in the frequency of mindfulness meditation from their normal life. This led to there being 8 observations in the treatment group and 12 in the control group. The results of the tests for this check can be seen in Appendix D7, D8 & D9. The only variables that changed in significance in this check was the difference between the treatment and control's correlation between self-estimated ambiguity attitude and their ambiguity aversion index which was significant at a 5% significance level ($z = 2.012$, $p = 0.022$). This was due to the correlation between estimated ambiguity attitudes and elicited ambiguity attitudes for the control group (r -0.6228, $p = 0.0305$) moving into significance at a 5% significance level. However, for this robustness check the assumptions of the Fischer Z transformation for Spearman Correlations does not hold, with the treatment sample size being under 10 observations ($n = 8$). The treatment groups correlation ($r = 0.3735$, $p = 0.362$) was still insignificant at a 10% significance level. Overall, this does not suggest much accuracy in either the treatment or control group, with the treatment group having an insignificant correlation, while the control groups negative correlation also indicating that they tended to be completely wrong in their predictions. The difference for estimated ambiguity insensitivity and elicited ambiguity insensitivity moved out of significance ($z = -0.845$, $p = 0.199$), becoming insignificant at a 10% significance level.

Discussion

Considering that the manipulation checks failed with there being no statistically significant difference between treatment and control's PHLMS scores, it suggests that the mindfulness intervention did not change how mindful the subjects are. In fact, the control group recorded a higher average state mindfulness score compared to the treatment further suggesting this. It was interesting to find that there was no significant correlation between my measures of state mindfulness (PHLMS) and trait mindfulness (MAAS) considering they both measure aspects relating to overall mindfulness. However, both trait and state mindfulness had significant correlations with intolerance to ambiguity (measured with MSTAT-II scale) although they were in different directions, with PHLMS having a negative correlation and MAAS having a positive correlation. This suggests that those who have higher trait mindfulness are likely to have higher tolerance to ambiguity, however that those who have higher state mindfulness have less tolerance to ambiguity.

The results of the experiment found no significant differences in tolerance to ambiguity, ambiguity aversion and ambiguity insensitivity, between participants who undertook a mindfulness meditation intervention for a week compared to subjects that played cognitive training games for a week. This suggests that mindfulness meditation does not have any causal effect on an individual's ambiguity attitudes, at least over the short-term. However, dropping subjects who did not report that they finished all 7-days of the intervention from the analysis resulted in a significant difference between treatment and control's ambiguity insensitivity index, with the treatment group having a higher median ambiguity insensitivity index than the control, suggesting that for those with little previous mindfulness experience, the mindfulness intervention made subjects more ambiguity insensitive, going against expectation. However, it should be noted that the subjects left after dropping observations for this robustness test was low.

There was also no significant correlation between ambiguity aversion and tolerance to ambiguity. This corroborates findings in previous literature which did not find a correlation between ambiguity intolerance measures and ambiguity aversion (Schröder & Freedman, 2020; Tanaka et al., 2015).

I found no significant correlation between self-estimated ambiguity attitudes and elicited ambiguity attitudes in either the treatment or control group. Interestingly, it was found that those with prior mindfulness experience estimated that they were more ambiguity seeking than those who had no previous experience, at a 5% significance level. However, there was no difference at a 10% significance level in ambiguity attitudes between those who had previous mindfulness experience and those who did not. This could suggest that mindfulness meditation (for a more prolonged period of time) makes people think that they can tolerate ambiguity better, however in reality, or at least in a decision-making scenario, they do no better than those who do not do mindfulness exercises. For this to be confirmed further studies are needed focusing on this as a question.

The treatment and control's individual correlations between self-estimated ambiguity insensitivity and elicited ambiguity insensitivity were insignificant, however the difference between the treatment and control correlations were statistically significant, due to the treatment having a positive correlation and the control having a negative correlation. This suggest some evidence that the treatment group were more accurate in predicting their ambiguity insensitivity, however it should be noted that the treatment groups correlation was still fairly low and insignificant, making the result inconclusive. This difference between correlations held throughout the first two robustness checks, being significant at a 10% significance level, but not the final robustness check, where it fell out of significance at a 10% significance level.

There are a number of limitations to this study. Firstly, the intervention was undertaken over a course a week. While there have been mindfulness studies that have had an efficacious effect over a small period of time (Creswell et al., 2014; Tang et al., 2007), the vast majority of the mindfulness literature test interventions over a longer period of time, for example, six weeks. In addition, it is likely that a personality trait such as ambiguity tolerance is unlikely to change in a person over a small period of time. Secondly, another limitation was the use of hypothetical choice. Dimmock et al. (2015) found that due to the complexity of ambiguous stimuli hypothetical choice did not perform well in comparison to incentivised choice.

Thirdly, I was also limited by sample size with only 33 participants finishing the intervention. This can explain the struggle to find significant results. This was highlighted by a lack of a normal distribution in many of my outcome variables. Further studies into mindfulness and ambiguity should strive to achieve a larger sample size. Fourthly, the subjects of the experiment were also acquaintances of the experimenter; hence the sample cannot be seen as representative of the whole population. Fifthly, the intervention was done over the internet, resulting in participants having to self-report if they used their assigned app as tasked. There was no way of confirming if participants had used their app daily for the assigned period without compromising their anonymity.

Seventhly, future studies should focus on individuals who had no meditation experience at all, as this would result in fewer confounding factors. Although in a robustness check I dropped observations who meditated less than weekly, the observation count left was low.

Eighthly, another limitation was the failure of the randomisation checks. The study was also plagued by a few confounding variables, namely previous mindfulness experience and mindfulness frequency. Both these variables were found to be associated self-estimated ambiguity aversion, with those with mindfulness experience and more frequent mediators being found to estimate that they were more ambiguity seeking. This suggests that those with meditation experience believe they are better at dealing with ambiguity. This led to a potential biasing of results for the correlation between self-estimates of ambiguity attitudes and elicited ambiguity insensitivity, due to these associations.

Lastly, there could also be potential issues with the external validity of the Ellsberg Urn experiment. Indeed, Fox & Tversky (1995) have already shown that ambiguity aversion was more strongly present when contrasting an ambiguous choice with a risky choice. This highlights concern over whether the experiment is an accurate depiction of how an individual would react to ambiguous probabilities in the real world. This is partly corroborated by the lack of a significant correlation between measures of tolerance to ambiguity and ambiguity aversion. Theoretically, ambiguity aversion should be a component of tolerance to ambiguity, however evidence suggests there is a limited association between the two. Whether this is because measures used to measure tolerance to ambiguity such as the MSTAT-II are unreliable or that ambiguity aversion is not external valid remains to be seen.

Conclusion

This paper tested mindfulness meditation as an intervention to improve how a person deals with ambiguity. I found no evidence to suggest that mindfulness meditation increases the ability to tolerate ambiguity in both the psychological and economic sense. I also found little correlation between the psychological measure of ambiguity (intolerance to ambiguity) and the economic measure of ambiguity (ambiguity attitudes) adding evidence to the literature that they are distinct measures. Testing to see how accurate participants estimated their own ambiguity attitudes and insensitivity provided ambiguous results, with statistically significant difference in correlation between treatment and control being found. However, the individual correlations lacked significance.

Further research into mindfulness and ambiguity is needed to see if longer term mindfulness interventions can have an effect on a subject's ability to deal with ambiguity. Hence, I recommend that future research in this area undertake an intervention over a longer period of time and that they use real incentives. In addition, I would recommend following up on participants a few months after the intervention, in order to see if there was a sustained change in how they respond to ambiguity. Finally, I would recommend future studies further investigate the relationship between ambiguity and anxiety, since reducing anxiety is one of the potential mechanisms of action through which mindfulness meditation could change how a person tolerates ambiguity. By measuring an individual's anxiety levels it is possible to see if anxiety mediates any potential relationship between mindfulness and ambiguity (if found) in a longer-term study.

References

Abdellaoui, M., Baillon, A., Placido, L., & Wakker, P. P. (2011). The Rich Domain of Uncertainty: Source Functions and Their Experimental Implementation. *American Economic Review*, *101*(2), 695–723. https://doi.org/10.1257/aer.101.2.695

Alem, Y., Behrendt, H., Belot, M., & Bíró, A. (2016). *Mind, Behaviour and Health: A Randomised Experiment* (SSRN Scholarly Paper ID 2803851). Social Science Research Network. http://papers.ssrn.com/abstract=2803851

Al-Najjar, N. I., & Weinstein, J. (2009). The Ambiguity Aversion Literature: A Critical Assessment. *Economics & Philosophy*, *25*(3), 249–284. https://doi.org/10.1017/S026626710999023X

Baer, R. A. (2003). Mindfulness Training as a Clinical Intervention: A Conceptual and Empirical Review. *Clinical Psychology: Science and Practice*, *10*(2), 125–143. https://doi.org/10.1093/clipsy.bpg015

Baillon, A., Huang, Z., Selim, A., & Wakker, P. P. (2018). Measuring Ambiguity Attitudes for All (Natural) Events. *Econometrica*, *86*(5), 1839–1858. https://doi.org/10.3982/ECTA14370

Bardi, A., Guerra, V. M., & Ramdeny, G. S. D. (2009). Openness and ambiguity intolerance: Their differential relations to well-being in the context of an academic life transition. *Personality and Individual Differences*, *47*(3), 219–223. https://doi.org/10.1016/j.paid.2009.03.003

Berger, L., Bleichrodt, H., & Eeckhoudt, L. (2013). Treatment decisions under ambiguity. *Journal of Health Economics*, *32*(3), 559–569. https://doi.org/10.1016/j.jhealeco.2013.02.001

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Speca, M., Velting, D., & Devins, G. (2004). Mindfulness: A Proposed Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Blanck, P., Perleth, S., Heidenreich, T., Kröger, P., Ditzen, B., Bents, H., & Mander, J. (2018). Effects of mindfulness exercises as stand-alone intervention on symptoms of anxiety and depression: Systematic review and meta-analysis. *Behaviour Research and Therapy*, *102*, 25–35. https://doi.org/10.1016/j.brat.2017.12.002

Bohlmeijer, E., Prenger, R., Taal, E., & Cuijpers, P. (2010). The effects of mindfulness-based stress reduction therapy on mental health of adults with a chronic medical disease: A meta-analysis. *Journal of Psychosomatic Research*, *68*(6), 539–544. https://doi.org/10.1016/j.jpsychores.2009.10.005

Bond, L., & Nolan, T. (2011). Making sense of perceptions of risk of diseases and vaccinations: A qualitative study combining models of health beliefs, decision-making and risk perception. *BMC Public Health*, *11*(1), 943. https://doi.org/10.1186/1471-2458-11-943

Brand, M., Grabenhorst, F., Starcke, K., Vandekerckhove, M. M. P., & Markowitsch, H. J. (2007). Role of the amygdala in decisions under ambiguity and decisions under risk: Evidence from patients with Urbach-Wiethe disease. *Neuropsychologia*, *45*(6), 1305–1317. https://doi.org/10.1016/j.neuropsychologia.2006.09.021

Budner, N. Y. S. (1962). Intolerance of ambiguity as a personality variable. *Journal of Personality*, *30*(1), 29–50. https://doi.org/10.1111/j.1467-6494.1962.tb02303.x

Burton, M., Schmertz, S. K., Price, M., Masuda, A., & Anderson, P. L. (2013). The Relation Between Mindfulness and Fear of Negative Evaluation Over the Course of Cognitive

Behavioral Therapy for Social Anxiety Disorder. *Journal of Clinical Psychology*, *69*(3), 222–228. https://doi.org/10.1002/jclp.21929

Cardaciotto, L., Herbert, J. D., Forman, E. M., Moitra, E., & Farrow, V. (2008). The Assessment of Present-Moment Awareness and Acceptance: The Philadelphia Mindfulness Scale. *Assessment*, *15*(2), 204–223. https://doi.org/10.1177/1073191107311467

Cardenas, J. C., & Carpenter, J. (2013). Risk attitudes and economic well-being in Latin America. *Journal of Development Economics*, *103*, 52–61. https://doi.org/10.1016/j.jdeveco.2013.01.008

Chambers, R., Lo, B. C. Y., & Allen, N. B. (2008). The Impact of Intensive Mindfulness Training on Attentional Control, Cognitive Style, and Affect. *Cognitive Therapy and Research*, *32*(3), 303–322. https://doi.org/10.1007/s10608-007-9119-0

Chew, S. H., Ebstein, R. P., & Zhong, S. (2012). Ambiguity aversion and familiarity bias: Evidence from behavioral and gene association studies. *Journal of Risk and Uncertainty*, *44*(1), 1–18. https://doi.org/10.1007/s11166-011-9134-0

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review*, *31*(3), 449–464. https://doi.org/10.1016/j.cpr.2010.11.003

Chiesa, A., & Serretti, A. (2009). Mindfulness-Based Stress Reduction for Stress Management in Healthy People: A Review and Meta-Analysis. *The Journal of Alternative and Complementary Medicine*, *15*(5), 593–600. https://doi.org/10.1089/acm.2008.0495

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, *30*(2), 203–216. https://doi.org/10.1016/j.cpr.2009.11.003

Creswell, J. D., Pacilio, L. E., Lindsay, E. K., & Brown, K. W. (2014). Brief mindfulness meditation training alters psychological and neuroendocrine responses to social evaluative stress. *Psychoneuroendocrinology*, *44*, 1–12. https://doi.org/10.1016/j.psyneuen.2014.02.007

Curley, S. P., Yates, J. F., & Abrams, R. A. (1986). Psychological sources of ambiguity avoidance. *Organizational Behavior and Human Decision Processes*, *38*(2), 230–256. https://doi.org/10.1016/0749-5978(86)90018-X

Dimmock, S. G., Kouwenberg, R., Mitchell, O. S., & Peijnenburg, K. (2016). Ambiguity aversion and household portfolio choice puzzles: Empirical evidence. *Journal of Financial Economics*, *119*(3), 559–577. https://doi.org/10.1016/j.jfineco.2016.01.003

Dimmock, S. G., Kouwenberg, R., & Wakker, P. P. (2015). Ambiguity Attitudes in a Large Representative Sample. *Management Science*, *62*(5), 1363–1380. https://doi.org/10.1287/mnsc.2015.2198

Ellsberg, D. (1961). Risk, Ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics*, *75*(4), 643–669. JSTOR. https://doi.org/10.2307/1884324

Fox, C. R., & Tversky, A. (1995). Ambiguity Aversion and Comparative Ignorance. *The Quarterly Journal of Economics*, *110*(3), 585–603. https://doi.org/10.2307/2946693

French, K. R., & Poterba, J. M. (1991). *Investor Diversification and International Equity Markets* (Working Paper No. 3609; Working Paper Series). National Bureau of Economic Research. https://doi.org/10.3386/w3609

Furnham, A., & Marks, J. (2013). Tolerance of Ambiguity: A Review of the Recent Literature. *Psychology*, *04*(09), 717–728.

Gilbert, P. (2001). Evolution and Social Anxiety: The Role of Attraction, Social Competition, and Social Hierarchies. *Psychiatric Clinics of North America*, *24*(4), 723–751. https://doi.org/10.1016/S0193-953X(05)70260-4

Gilboa, I., & Schmeidler, D. (1989). Maxmin expected utility with non-unique prior. *Journal of Mathematical Economics*, *18*(2), 141–153. https://doi.org/10.1016/0304-4068(89)90018-9

Goldin, P., Ramel, W., & Gross, J. (2009). Mindfulness Meditation Training and Self-Referential Processing in Social Anxiety Disorder: Behavioral and Neural Effects. *Journal of Cognitive Psychotherapy*, *23*(3), 242–257. https://doi.org/10.1891/0889-8391.23.3.242

Goyal, M., Singh, S., Sibinga, E. M. S., Gould, N. F., Rowland-Seymour, A., Sharma, R., Berger, Z., Sleicher, D., Maron, D. D., Shihab, H. M., Ranasinghe, P. D., Linn, S., Saha, S., Bass, E. B., & Haythornthwaite, J. A. (2014). Meditation Programs for Psychological Stress and Well-being: A Systematic Review and Meta-analysis. *JAMA Internal Medicine*, *174*(3), 357–368. https://doi.org/10.1001/jamainternmed.2013.13018

Grenier, S., Barrette, A.-M., & Ladouceur, R. (2005). Intolerance of Uncertainty and Intolerance of Ambiguity: Similarities and differences. *Personality and Individual Differences*, *39*(3), 593–600. https://doi.org/10.1016/j.paid.2005.02.014

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of Psychosomatic Research*, *57*(1), 35–43. https://doi.org/10.1016/S0022-3999(03)00573-7

Hafenbrack, A., Kinias, Z., & Barsade, S. (2014). Debiasing the Mind Through Meditation: Mindfulness and the Sunk-Cost Bias. *Psychological Science*, *25*(2), 369–376.

Han, P. K. J., Reeve, B. B., Moser, R. P., & Klein, W. M. P. (2009). Aversion to Ambiguity Regarding Medical Tests and Treatments: Measurement, Prevalence, and Relationship to Sociodemographic Factors. *Journal of Health Communication*, *14*(6), 556–572. https://doi.org/10.1080/10810730903089630

Hardy, J. L., Nelson, R. A., Thomason, M. E., Sternberg, D. A., Katovich, K., Farzin, F., & Scanlon, M. (2015). Enhancing Cognitive Abilities with Comprehensive Training: A Large, Online, Randomized, Active-Controlled Trial. *PLOS ONE*, *10*(9), e0134467. https://doi.org/10.1371/journal.pone.0134467

Hartley, C. A., & Phelps, E. A. (2012). Anxiety and Decision-Making. *Biological Psychiatry*, *72*(2), 113–118. https://doi.org/10.1016/j.biopsych.2011.12.027

Hazen, B. T., Overstreet, R. E., Jones-Farmer, L. A., & Field, H. S. (2012). The role of ambiguity tolerance in consumer perception of remanufactured products. *International Journal of Production Economics*, *135*(2), 781–790.

Headspace. (2020). Headspace. https://www.headspace.com/

Heimberg, R. G., Brozovich, F. A., & Rapee, R. M. (2010). A Cognitive Behavioral Model of Social Anxiety Disorder: Update and Extension. In S. G. Hofmann & P. M. DiBartolo (Eds.), *Social Anxiety* (Second Edition, pp. 395–422). Academic Press. https://doi.org/10.1016/B978-0-12-375096-9.00015-8

Hill, C. L. M., & Updegraff, J. A. (2012). Mindfulness and its relationship to emotional regulation. *Emotion*, *12*(1), 81–90. https://doi.org/10.1037/a0026355

Hofmann, S. G., Sawyer, A. T., Witt, A. A., & Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of Consulting and Clinical Psychology*, *78*(2), 169–183. https://doi.org/10.1037/a0018555

Ie, A., Haller, C. S., Langer, E. J., & Courvoisier, D. S. (2012). Mindful multitasking: The relationship between mindful flexibility and media multitasking. *Computers in Human Behavior*, *28*(4), 1526–1532. https://doi.org/10.1016/j.chb.2012.03.022

Kabat-Zinn, J. (2003). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Khoury, B., Lecomte, T., Fortin, G., Masse, M., Therien, P., Bouchard, V., Chapleau, M.-A., Paquin, K., & Hofmann, S. G. (2013). Mindfulness-based therapy: A comprehensive meta-analysis. *Clinical Psychology Review*, *33*(6), 763–771. https://doi.org/10.1016/j.cpr.2013.05.005

Kirk, U., Gu, X., Sharp, C., Hula, A., Fonagy, P., & Montague, P. R. (2016). Mindfulness training increases cooperative decision making in economic exchanges: Evidence from fMRI. *NeuroImage*, *138*, 274–283. https://doi.org/10.1016/j.neuroimage.2016.05.075

Kirton, M. J. (1981). A Reanalysis of Two Scales of Tolerance of Ambiguity. *Journal of Personality Assessment*, *45*(4), 407–414. https://doi.org/10.1207/s15327752jpa4504_10

Kruglanski, A. W., Webster, D. M., & Klem, A. (1993). Motivated resistance and openness to persuasion in the presence or absence of prior information. *Journal of Personality and Social Psychology*, *65*(5), 861–876. https://doi.org/10.1037/0022-3514.65.5.861

Lumosity Brain Training: Challenge & Improve Your Mind. (2020). Lumosity. https://www.lumosity.com/en/

Lyvers, M., Makin, C., Toms, E., Thorberg, F. A., & Samios, C. (2014). Trait Mindfulness in Relation to Emotional Self-Regulation and Executive Function. *Mindfulness*, *5*(6), 619–625. https://doi.org/10.1007/s12671-013-0213-y

MacKillop, J., & Anderson, E. J. (2007). Further Psychometric Validation of the Mindful Attention Awareness Scale (MAAS). *Journal of Psychopathology and Behavioral Assessment*, *29*(4), 289–293. https://doi.org/10.1007/s10862-007-9045-1

MacLeod, C., & Mathews, A. (2012). Cognitive Bias Modification Approaches to Anxiety. *Annual Review of Clinical Psychology*, *8*(1), 189–217. https://doi.org/10.1146/annurev-clinpsy-032511-143052

McLain, D. L. (2009). Evidence of the Properties of an Ambiguity Tolerance Measure: The Multiple Stimulus Types Ambiguity Tolerance Scale–II (MSTAT–II). *Psychological Reports*, *105*(3), 975–988. https://doi.org/10.2466/PR0.105.3.975-988

Missier, F. D., Mäntylä, T., & Bruin, W. B. de. (2010). Executive functions in decision making: An individual differences approach. *Thinking & Reasoning*, *16*(2), 69–97. https://doi.org/10.1080/13546781003630117

Noone, C., Bunting, B., & Hogan, M. J. (2016). Does Mindfulness Enhance Critical Thinking? Evidence for the Mediating Effects of Executive Functioning in the Relationship between Mindfulness and Critical Thinking. *Frontiers in Psychology*, *6*. https://doi.org/10.3389/fpsyg.2015.02043

Ortner, C. N. M., Kilner, S. J., & Zelazo, P. D. (2007). Mindfulness meditation and reduced emotional interference on a cognitive task. *Motivation and Emotion*, *31*(4), 271–283. https://doi.org/10.1007/s11031-007-9076-7

Ostafin, B. D., Brooks, J. J., & Laitem, M. (2014). Affective Reactivity Mediates an Inverse Relation Between Mindfulness and Anxiety. *Mindfulness*, *5*(5), 520–528. https://doi.org/10.1007/s12671-013-0206-x

Parcerisa, C. (2019, October 24). *Can mindfulness actually help you work smarter?* Google. https://blog.google/inside-google/life-at-google/mindfulness-at-work/

Pilisuk, M., Potter, P., Rapoport, A., & Winter, J. A. (1965). War Hawks and Peace Doves: Alternate resolutions of experimental conflicts. *Journal of Conflict Resolution*, *9*(4), 491–508. https://doi.org/10.1177/002200276500900406

Raglan, G. B. (2014). Decision Making, Mindfulness and Mood: How Mindfulness Techniques can Reduce the Impact of Biases and Heuristics through Improved Decision Making and Positive Affect. *Journal of Depression and Anxiety*, *04*(01). https://doi.org/10.4172/2167-1044.1000168

Ritov, I., & Baron, J. (1990). Reluctance to vaccinate: Omission bias and ambiguity. *Journal of Behavioral Decision Making*, *3*(4), 263–277. https://doi.org/10.1002/bdm.3960030404

Robinson, J. (2019). *Mindfulness, Tolerance of Ambiguity, and Attitudes Toward Interracial Relationships* [Doctoral Dissertation, Alliant International University]. https://search.proquest.com/openview/cea0e511e59c14b2756fa353faac720a/1?pq-origsite=gscholar&cbl=18750&diss=y

Savage, L. (1954). *The foundations of statistics* (Vol. 1). http://onlinelibrary.wiley.com/doi/abs/10.1002/nav.3800010316

Schröder, D., & Freedman, G. G. (2020). Decision making under uncertainty: The relation between economic preferences and psychological personality traits. *Theory and Decision*, 1–23. https://doi.org/10.1007/s11238-019-09742-3

Semple, R. J. (2010). Does Mindfulness Meditation Enhance Attention? A Randomized Controlled Trial. *Mindfulness*, *1*(2), 121–130. https://doi.org/10.1007/s12671-010-0017-2

Shapiro, S. L., Jazaieri, H., & Goldin, P. R. (2012). Mindfulness-based stress reduction effects on moral reasoning and decision making. *The Journal of Positive Psychology*, *7*(6), 504–515. https://doi.org/10.1080/17439760.2012.723732

Sherman, R. (1974). The Psychological Difference Between Ambiguity and Risk. *The Quarterly Journal of Economics*, *88*(1), 166–169. JSTOR. https://doi.org/10.2307/1881806

Sheskin, D. J. (2003). *Handbook of Parametric and Nonparametric Statistical Procedures* (Third Edition). Chapman and Hall/CRC. https://doi.org/10.1201/9781420036268

Snow, A. (2011). Ambiguity aversion and the propensities for self-insurance and self-protection. *Journal of Risk and Uncertainty*, *42*(1), 27–43. https://doi.org/10.1007/s11166-010-9112-y

Strack, F., & Deutsch, R. (2004). Reflective and Impulsive Determinants of Social Behavior. *Personality and Social Psychology Review*, *8*(3), 220–247. https://doi.org/10.1207/s15327957pspr0803_1

Tanaka, Y., Fujino, J., Ideno, T., Okubo, S., Takemura, K., Miyata, J., Kawada, R., Fujimoto, S., Kubota, M., Sasamoto, A., Hirose, K., Takeuchi, H., Fukuyama, H., Murai, T., & Takahashi, H. (2015). Are ambiguity aversion and ambiguity intolerance identical? A neuroeconomics investigation. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.01550

Tang, Y.-Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M. K., Fan, M., & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences*, *104*(43), 17152–17156. https://doi.org/10.1073/pnas.0707678104

Teoh, H. Y., & Foo, S. L. (1997). Moderating effects of tolerance for ambiguity and risktaking propensity on the role conflict-perceived performance relationship: Evidence from singaporean entrepreneurs. *Journal of Business Venturing*, *12*(1), 67–81.

Teper, R., & Inzlicht, M. (2013). Meditation, mindfulness and executive control: The importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience*, *8*(1), 85–92. https://doi.org/10.1093/scan/nss045

Teper, R., Segal, Z. V., & Inzlicht, M. (2013). Inside the Mindful Mind: How Mindfulness Enhances Emotion Regulation Through Improvements in Executive Control. *Current Directions in Psychological Science*, *22*(6), 449–454. https://doi.org/10.1177/0963721413495869

Toneatto, T., & Nguyen, L. (2007). Does Mindfulness Meditation Improve Anxiety and Mood Symptoms? A Review of the Controlled Research. *The Canadian Journal of Psychiatry*, *52*(4), 260–266. https://doi.org/10.1177/070674370705200409

Trautmann, S. T., Vieider, F. M., & Wakker, P. P. (2008). Causes of ambiguity aversion: Known versus unknown preferences. *Journal of Risk and Uncertainty*, *36*(3), 225–243. https://doi.org/10.1007/s11166-008-9038-9

Unilever. (n.d.). *Our health & well-being programmes in action*. Unilever. Retrieved January 24, 2021, from https://www.unilever.com/sustainable-living/enhancing-livelihoods/fairness-in-the-workplace/improving-employee-health-and-well-being/our-health-and-well-being-programmes-in-action/

Vago, D. R. P. D., & David, S. A. M. D. (2012). Self-awareness, self-regulation, and self-transcendence (S-ART): A framework for understanding the neurobiological mechanisms of mindfulness. *Frontiers in Human Neuroscience*, *6*. https://doi.org/10.3389/fnhum.2012.00296

Van Hook, C. W., & Steele, C. (2002). Individual Personality Characteristics Related to Suggestibility. *Psychological Reports*, *91*(3), 1007–1010. https://doi.org/10.2466/pr0.2002.91.3.1007

Warnick, J. C. E., Escobal, J., & Laszlo, S. C. (2011). Ambiguity Aversion and Portfolio Choice in Small-Scale Peruvian Farming. *The B.E. Journal of Economic Analysis & Policy*, *11*(1). https://doi.org/10.2202/1935-1682.2331

West, R., Toplak, M., & Stanovich, K. (2008). Heuristics and Biases as Measures of Critical Thinking: Associations with Cognitive Ability and Thinking Dispositions. *Journal of Educational Psychology*, *100*(4), 930.

Williams, J. M., Watts, F., Macleod, C., & Matthews, A. (1997). *Cognitive Psychology and Emotional Disorders* (2nd Edition). JW. https://www.wiley.com/en-us/Cognitive+Psychology+and+Emotional+Disorders%2C+2nd+Edition-p-9780471944300

Yurtsever, G. (2001). Tolerance of Ambiguity, Information, and Negotiation. *Psychological Reports*, *89*(1), 57–64. https://doi.org/10.2466/pr0.2001.89.1.57

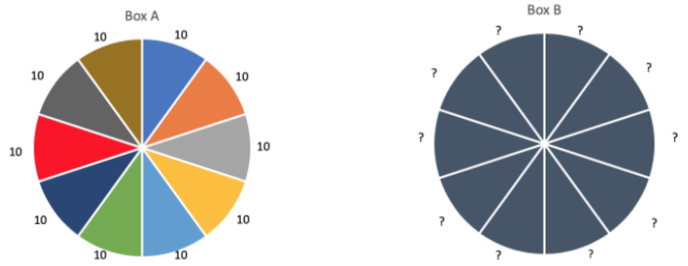
Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition*, *19*(2), 597–605. https://doi.org/10.1016/j.concog.2010.03.014

Appendix A

Ambiguity Attitude Survey Questions

Figure A1

Preference Elicitation Question (10% Probability level of success)



Both boxes have a total of 100 balls in them of 10 different colours. One ball will be drawn from the box of your choice.

IF the ball drawn from the box is red, you win 25 euros. If it is any other color, you lose.

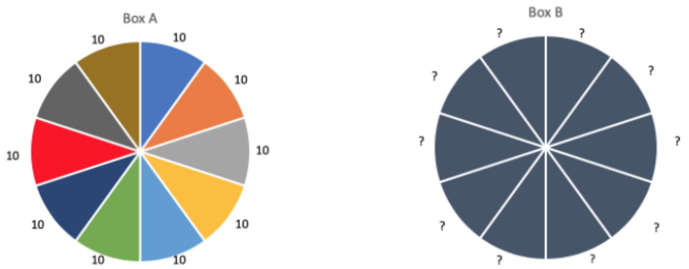
For Box A you can see the exact proportion of colored balls.
Box B also contains 10 different colours of balls, but the proportions are not known in advanced.

Which box do you prefer to draw from?

- Box A
- Box B
- Indifferent

Figure A2

Preference Elicitation Question (90% Probability level of success)



Both boxes have a total of 100 balls in them of 10 different colours. One ball will be drawn from the box you have chosen.

IF a ball is drawn of any color OTHER THAN red, you win 25 euros. If a red ball is drawn you lose.

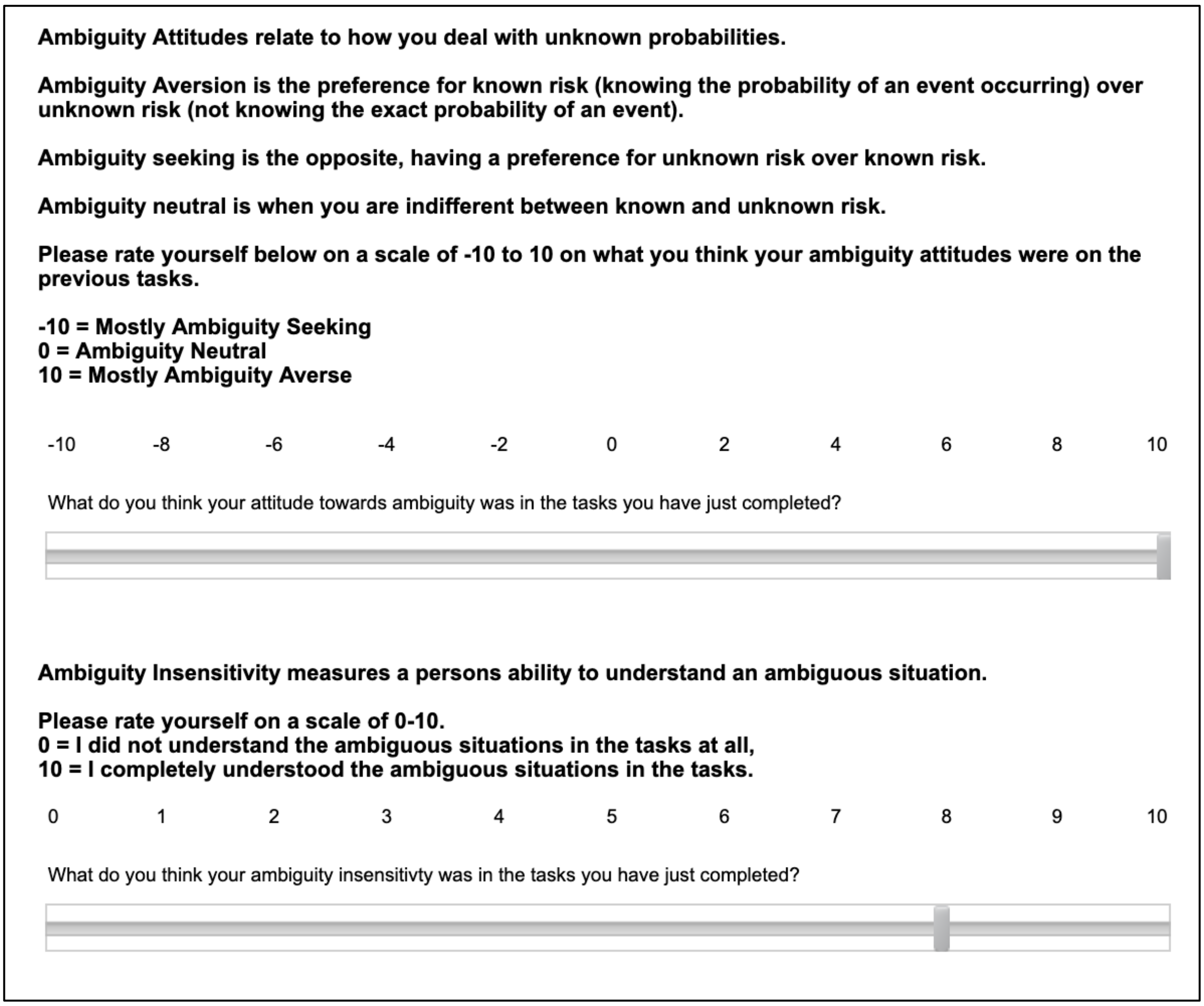
For Box A you can see the exact proportion of colored balls.
Box B also contains 10 different colours of balls, but the proportions are not known in advanced.

Which box do you prefer to draw from?

- Box A
- Box B
- Indifferent

Figure A3

Self-Estimate of Ambiguity Attitude & Insensitivity Questions



Ambiguity Attitudes relate to how you deal with unknown probabilities.

Ambiguity Aversion is the preference for known risk (knowing the probability of an event occurring) over unknown risk (not knowing the exact probability of an event).

Ambiguity seeking is the opposite, having a preference for unknown risk over known risk.

Ambiguity neutral is when you are indifferent between known and unknown risk.

Please rate yourself below on a scale of -10 to 10 on what you think your ambiguity attitudes were on the previous tasks.

-10 = Mostly Ambiguity Seeking
0 = Ambiguity Neutral
10 = Mostly Ambiguity Averse

-10 -8 -6 -4 -2 0 2 4 6 8 10

What do you think your attitude towards ambiguity was in the tasks you have just completed?

Ambiguity Insensitivity measures a persons ability to understand an ambiguous situation.

Please rate yourself on a scale of 0-10.
0 = I did not understand the ambiguous situations in the tasks at all,
10 = I completely understood the ambiguous situations in the tasks.

0 1 2 3 4 5 6 7 8 9 10

What do you think your ambiguity insensitivty was in the tasks you have just completed?

Appendix B

Internal Consistency of Scales and Normality of Outcome Variables

Table B1

Internal Consistency of Scales

Variables	Cronbach-Alpha
MAAS	0.778
PHLMS	0.852
Acceptance Subscale	0.896
Awareness Subscale	0.828
MSTAT-II	0.832

Table B2:

Shapiro Wilk W-Test & Skewness-Kurtosis Test for Normality of Outcome Variable

Variables	W-Statistic	Probability of Skewness	Probability of Kurtosis	Joint Probability
Ambiguity Aversion	0.880*	0.019**	0.099*	0.026**
Ambiguity Insensitivity	0.903*	0.235	0.011**	0.023**
MSTAT-II Score	0.948	0.376	0.063*	0.114
Self-Estimate Ambiguity Aversion	0.977	0.509	0.238	0.374
Self-Estimate Ambiguity Insensitivity	0.995	0.813	0.519	0.784
MAAS	0.903	0.005***	0.289	0.02**
PHLMS	0.993	0.986	0.83	0.977

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: W-Stastic is from Shapiro Wilk W-Test. Skewness, Kurtosis and joint probability are values from the Skewness Kurtosis Test

Appendix C

Mann-Whitney U Test Table for Non-Normally Distributed Outcome Variables

Variable	Mean Rank		Z-Value
	Control (17)	Treatment (16)	
Ambiguity Aversion Index	16	18.063	-0.615
Ambiguity Insensitivity Index	15.853	18.219	-0.706
$AA_{0.1}$	15.176	18.938	-1.129
$AA_{0.5}$	16.118	17.938	-0.549
$AA_{0.9}$	16.941	17.063	-0.036

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Appendix D

Robustness Test Results

Table D1

7 Days Completed Robustness Check Results – Normally Distributed Variables

Demographic	Control (14)		Treatment (7)				
	Mean	SD	Mean	SD	Difference	$t(19)$	p
MSTAT-II	3.478	.633	3.451	.543	.027	0.098	0.539
Self-Estimated Ambiguity Aversion	1.071	1.273	-.714	2.36	.476	0.732	0.238
Self-Estimated Ambiguity Insensitivity	6.071	.675	6.571	.841	.5	-0.444	0.669

*** p<0.01, ** p<0.05, * p<0.1

Table D2

7 Days Completed Robustness Check Results – Non-normal Distributed Variables

Demographic	Control (14)			Treatment (7)			Difference
	Median	Min	Max	Median	Min	Max	
Ambiguity Aversion Index	.035	-.24	.843	.08	-.556	.883	.045
Ambiguity Insensitivity Index	.25	0	1	.75	0	1	.5
$AA_{0.1}$	0	-40	3	-1	-65	9	1
$AA_{0.5}$	1.5	0	43.5	4.5	-31.5	43.5	3
$AA_{0.9}$	10	-9	80	13	-9	80	3

*** p<0.01, ** p<0.05, * p<0.1

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Table D3

7 – Days Completed Robustness Check Results: Non-Normally Distributed Variables – Differences between treatment & control (Mann-Whitney U test)

Variable	Mean Rank		Z-Value
	Control (14)	Treatment (7)	
Ambiguity Aversion Index	11.036	10.929	0.038
Ambiguity Insensitivity Index	9.393	14.214	-1.690*
$AA_{0.1}$	11.286	10.429	0.302
$AA_{0.5}$	10.893	11.214	-0.115
$AA_{0.9}$	10.75	11.5	-0.263

*** p<0.01, ** p<0.05, * p<0.1

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Table D4

Inconsistent Preferences Dropped Robustness Check Results – Normally Distributed Variables

Demographic	Control (17)		Treatment (13)				
	Mean	SD	Mean	SD	Difference	*t*(28)	*p*
MSTAT-II	3.434	.591	3.538	.509	.104	-0.507	0.308
Self-Estimated Ambiguity Aversion	.765	5.203	0	5.462	.765	0.391	0.350
Self-Estimated Ambiguity Insensitivity	6.176	2.298	6.308	1.797	.131	-0.170	0.567

*** p<0.01, ** p<0.05, * p<0.1

Table D5

Inconsistent Preferences Dropped Robustness Check – Non-normal Distributed Variables

Demographic	Control (17)			Treatment (13)			Difference
	Median	Min	Max	Median	Min	Max	
Ambiguity Aversion Index	0	-.24	.843	.08	-.556	.883	.08
Ambiguity Insensitivity Index	.263	0	1	.538	0	1	0.275
$AA_{0.1}$	0	-40	3	0	-65	9	0
$AA_{0.5}$	0	-22	43.5	1.5	-31.5	43.5	1.5
$AA_{0.9}$	19	-9	80	13	-9	80	6

*** p<0.01, ** p<0.05, * p<0.1

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Table D6

Inconsistent Preferences Dropped Robustness Check: Non-Normally Distributed Variables – Differences between treatment & control (Mann-Whitney U test)

Variable	Mean Rank		Z-Value
	Control (17)	Treatment (13)	
Ambiguity Aversion Index	14.294	17.077	-0.863
Ambiguity Insensitivity Index	13.706	17.846	-1.282
$AA_{0.1}$	14.618	16.654	-0.634
$AA_{0.5}$	14.324	17.038	-0.854
$AA_{0.9}$	14.735	16.5	-0.547

*** p<0.01, ** p<0.05, * p<0.1

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Table D7

Frequent Meditators Dropped Robustness Check Results – Normally Distributed Variables

Demographic	Control (12)		Treatment (8)				
	Mean	SD	Mean	SD	Difference	*t*(18)	*p*
MSTAT-II	3.372	.521	3.279	.561	.093	0.380	0.354
Self-Estimated Ambiguity Attitude	1.583	5.195	1.125	4.121	.458	0.209	0.418
Self-Estimated Ambiguity Insensitivity	5.833	2.329	5.875	2.167	.042	-0.040	0.519

*** p<0.01, ** p<0.05, * p<0.1

Table D8

Frequent Meditators Dropped Robustness Check Results – Non-normal Distributed Variables

Demographic	Control (12)			Treatment (8)			Difference
	Median	Min	Max	Median	Min	Max	
Ambiguity Aversion Index	.008	-.24	.843	.03	-.153	.883	.022
Ambiguity Insensitivity Index	.25	0	1	.05	0	.888	.2
$AA_{0.1}$	-1	-40	3	0	-20	9	1
$AA_{0.5}$	0	-11	43.5	1.5	-13	43.5	1.5
$AA_{0.9}$	10	-9	80	5	-1	80	5

*** p<0.01, ** p<0.05, * p<0.1

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%

Table D9

Frequent Meditators Dropped Robustness Check: Non-Normally Distributed Variables – Differences between treatment & control (Mann-Whitney U test)

Variable	Mean Rank		Z-Value
	Control (12)	Treatment (8)	
Ambiguity Aversion Index	10.125	11.063	-0.348
Ambiguity Insensitivity Index	11	9.75	0.467
$AA_{0.1}$	8.958	12.75	-1.447
$AA_{0.5}$	10.042	11.188	-0.432
$AA_{0.9}$	10.458	10.563	-0.039

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

$AA_{0.1}$ = Local Ambiguity Index at probability of 10%

$AA_{0.5}$ = Local Ambiguity Index at probability of 50%

$AA_{0.9}$ = Local Ambiguity Index at probability of 90%