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AUTHOR: Kathryn Jewell Shaw

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Dr. Sharon Hamill THESIS COMMITTEE CHAIR	Sharon B. Hamill SIGNATURE	5/5/17 DATE
Dr. Dustin Calvillo THESIS COMMITTEE MEMBER	SIGNATURE	5/5/17 DATE
Dr. Sara Bufferd THESIS COMMITTEE MEMBER	S. Buffer SIGNATURE	5/5/17 DATE

Problematic Phone Use and Phantom Notifications:

An Examination of Normative Hallucinations

Kathryn Jewell Shaw

California State University San Marcos

Abstract

Historically, hallucinations have been labeled only as symptoms of clinical disorders; however, research over the past few decades has suggested hallucinations can occur in individuals without a clinical diagnosis. Previous studies have shown that as many as 40% of the general population has reported experiencing hallucinations. Theories suggest that normative hallucinations arise due to issues with internal-external source monitoring and the experience of high stress. One way these hallucinations may manifest is through phantom vibration syndrome, or imagined cell phone notifications. It is possible that problematic phone use increases an individual's susceptibility to phantom notifications. The present study investigated predictive factors of phantom notifications, hypothesizing that source monitoring ability would be related to the experience of phantom notifications, and that problematic phone use and perceived stress will moderate this relationship. In addition, it was hypothesized that an individual's predisposition to hallucinate would be related to phantom notifications and that perceived stress would moderate this relationship. Two hundred and one undergraduate students participated in both a source monitoring task and a self-report survey, in which predispositions to hallucinate, perceived stress, problematic phone habits, and the frequency of phantom notifications were measured. Results of the study indicated that source monitoring ability was not related to the frequency of phantom notifications, but that problematic phone use, perceived stress, and hallucination proneness were all related to phantom notifications. Additionally, problematic phone use emerged as the strongest predictor of phantom notifications. These results suggest that phantom notifications are normative hallucinations and that problematic phone use is instrumental in these experiences. These results also provide support for the continuum view of hallucinations and suggest that further research is needed to explore the influences of phone use on mental health.

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Problematic Phone Use and Phantom Notifications: An Examination of Normative Hallucinations

On April 3rd, 1973 Martin Cooper, a Motorola employee, made the first cell phone call to the office of Bell Labs while standing in the middle of Manhattan, New York (Seward, 2013). Since that date, the world has experienced a surge of cell phone use— an innovation that has allowed people from around the globe to stay connected with each other. However, the rise of cell phones has not only affected the way people connect with each other, but has infiltrated other aspects of life, such as driving habits (Sanbonmatsu, Strayer, Biondi, Behrends, & Moore, 2016), academic performance (Bjornsen & Archer, 2015), and sleep (Li, Lepp, & Barkley, 2015). Cell phones have even affected walking: 17% of American adults have reported being so engrossed in their cell phones that they have walked into another person or object (Madden & Rainie, 2010); in some cases, walking while using a cell phone has even led to the user's death (Office of Compliance, 2010).

Most Americans check their phones frequently, regardless of whether someone has called or not, and almost half of all adult cell phone users sleep with their phones so as not to miss a call (Smith, 2012). In fact, 82% of cell phone users have reported experiencing imaginary calls or texts by others, which is evidence of illusory sensory stimuli such as phantom cell phone notifications (Tanis, Beukeboom, Hartmann, & Vermeulen, 2015). These notifications or "phantom vibration syndrome" occur when a person hears or feels the vibration or ringing of a cell phone notification, although no such notification was received (Rosenberger, 2015). Why do people experience sensory stimuli when in fact, no stimulation has occurred? It may be that phantom notifications are a manifestation of normative hallucinations, though to date this explanation has only been speculative (Rosenberger, 2015; Rothberg, Arora, Hermann, Kleppel, Marie & Visintainer, 2010).

Hallucinations have been portrayed in popular culture as symptoms of “insanity,” although previous studies have shown that nearly 40% of the general population has experienced a hallucination at some point in his or her life (Ohayon, 2000). Hallucinations that occur without any underlying clinical disorder or as a result of substance will be referred to as normative hallucinations. To gain insight into normative hallucinations, it is imperative to investigate the occurrence of phantom vibration syndrome, and identify factors that might predict and explain this phenomenon.

The present paper begins with a description of the nature of hallucinations, including an overview of normative hallucinations. Second, the theoretical background regarding the origin of hallucinations will be discussed. Next, findings from the literature on phantom notifications will be reported. Finally, this paper will present a study that examines predictors of phantom notifications, and possible moderating effects of perceived stress and excessive phone use on perceptions.

The Nature of Hallucinations

Throughout history, the definition of hallucinations has changed drastically, ranging from visions of God and witchcraft, to symptoms of a pathological disorder (Telles-Correia, Moreira, & Gonçalves, 2015). For the purposes of this paper, hallucinations will be defined as sensory perceptions in the absence of a stimulus, in which the person experiencing the event believes such perceptions to be reality. Not only are hallucinations perceived in the absence of stimuli, but they also lack controllability; if one could control a hallucination, it would be considered fantasy (Benjamin, 1997). To best understand hallucinations, consideration must first be given to the different types of hallucinations and clinical disorders associated with these symptoms.

Hallucinations can occur in any sensory modality. Auditory-verbal and visual hallucinations are the most widely studied forms of hallucinations, often manifested by hearing voices (Barrett & Etheridge, 1992) or music (Coebergh, Lauw, Bots, Sommer, & Blom, 2015), or by seeing objects that are not there (Gibson et al., 2013). Although most research focuses on auditory-verbal and visual hallucinations, a large-scale study with over 13,000 participants suggests that the most common forms of hallucinations experienced in the general population are olfactory (affecting the sense of smell) and gustatory (affecting taste; Ohayon, 2000). Hallucinations can also take the form of a "presence." For example, some individuals feel as if there is someone in the room when there is not (Stip & Letourneau, 2009). The hallucination can also be tactile in nature, such as experiencing the feeling of crawling insects (Ohayon, 2000). However, in addition to the sensory modality in which they occur, hallucinations also differ in terms of the disorder or disease of which they are a symptom.

Much of what is known about hallucinations stems from research focusing on brain diseases and substance use. Schizophrenia (Tandon et al., 2013), neurodegenerative diseases, such as Alzheimer's disease and Parkinson's disease (Grossi, Carotenuto, Trojano, Manzo, & Fasanaro, 2011), and epilepsy (Korsnes, Hugdahl, Nygard, & Bjornaes, 2010) all include hallucinations as symptoms of the specific illness. For example, individuals with schizophrenia are often characterized by experiencing auditory-verbal hallucinations in the form of negative voices that ultimately become so severe that problems begin to develop socially or in the workplace (Larøi et al., 2012). Hallucinations can also be drug-induced. Hallucinogenic drugs such as lysergic acid diethylamide (LSD), psilocybin mushrooms, and mescaline can induce hallucinations including bright, exaggerated colors, spatial/ depth distortion, and even animations (Iaria, Fox, Scheel, Stowe, Barton, 2010; Riley & Blackman, 2008). From investigating disease and drug-induced hallucinations, it is clear that almost any sensory perception can occur as a hallucination. Although this body of literature is dominated by research on clinical hallucinations, hallucinations have also been seen to occur in individuals without such diagnoses.

Normative hallucinations. Normative hallucinations do not occur as a direct result of a brain disease or drug use, and often are manifested as an inability to discriminate between what is real and what is not. One example of a normative hallucination occurs during childhood. Children often display difficulties discriminating between imagination and reality. Although imagination is distinct from hallucinations, during childhood this distinction is not as clear; for example, a child can display real fear in response to an imagined monster (Kayyal & Widen, 2013) or might have an imaginary friend (Burbach, Roberts, Clinch, & Wise, 2014). These experiences during childhood are seen as normative occurrences, and are even considered positive developmental characteristics because they reflect children's ability to adapt to psychologically stressful events (Burbach et al., 2014). The extant literature on normative hallucinations is equivocal regarding how they are distinguished from hallucinations indicative of a clinical disorder, and the factors that make some individuals more prone to them than others.

Even if hallucinations are experienced by most people in early childhood, these hallucinations are not necessarily indicative of a clinical disorder. In addition, there are many differences between normative and clinical hallucinations. For instance, normative hallucinations often occur less frequently, are less vivid, and do not have the same negative effects on the individual as do clinical-level hallucinations (Daalman et al., 2011; Honig, Romme, Ensink, Escher, Pennings, & deVries, 1998). Additionally, the continued belief of the hallucinations' reality often distinguishes normative from clinical hallucinations (Ohayon, 2000). For instance, people who experienced clinical hallucinations were more likely to continue to believe that the hallucination was real than people who experienced normative hallucinations (Ohayon, 2000). Most individuals who experience normative hallucinations do so without ever developing any form of psychosis; however, if hallucinations persist over time and other deficits in functioning occur, the individual may be more likely to develop a form of psychosis, reflecting the more severe end of the hallucination spectrum (De Loore et al., 2011). It is important to note that some researchers do not believe in the existence of normative hallucinations and have implied such experiences are not "true" hallucinations (Telles-Correia et al., 2015). However, the proposed continuum view of hallucinations may offer a context in which normative hallucinations can be explained.

Hallucination continuum. The continuum view of hallucinations gradually distinguishes normative hallucinations from clinical-level hallucinations (Ohayon, 2000), and suggests that individuals can be placed along the continuum as their hallucinations increase or decrease in severity. A study conducted by van Os, Hanssen, Bijl, and Ravelli (2000) revealed that among individuals interviewed from the general population, 6.2% of participants reported normative hallucinations, and only 1.7% of the sample reported having clinical-level hallucinations indicative of psychosis (van Os et al., 2000). The fact that research shows individuals vary from having no hallucinatory experiences to those with many hallucinations and a psychotic diagnosis led to a continuum view of hallucinations in which individuals with no hallucinations are placed on one side of the continuum, followed by normative and less severe hallucinations, and individuals with clinical-level and more severe hallucinations placed on the other side (see Figure 1). This placement on the continuum may or may not coincide with an actual diagnosis of psychosis, as hallucinations are only one feature of psychotic disorders. However, the continuum view of hallucinations is largely supported by the literature (Krabbendam, Myin-Germeys, Bak, & van Os, 2005; Stip & Letourneau, 2009). For example, in situations such as bereavement or worship, hallucinations do not necessarily lead to a psychotic diagnosis (Kersting, 2004; Stip & Letourneau, 2009). A variety of factors, such as severity, vividness, frequency, and the continued belief in the reality of the hallucination would influence where the individual is placed on the continuum (Ohayon, 2000). Collectively, these studies suggest that all individuals can be placed at some point along the continuum and it is important to identify factors that may predict one's placement.

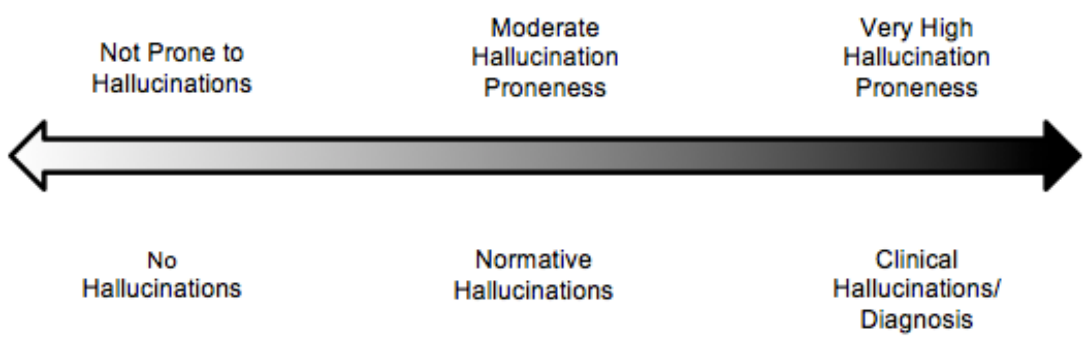

Figure 1. The hallucination continuum gradually progresses from no hallucinations, normative hallucinations, to clinical hallucinations. The level of hallucination proneness indicates where an individual falls on the continuum.

Hallucination proneness. Hallucination proneness, or one's predisposition to experience a hallucination, can indicate where an individual falls on the proposed hallucination continuum. First measured by Launay and Slade (1981), these researchers focused on quantifying an individual's hallucination proneness so as to predict how likely he or she is to experience a hallucination. A sample statement from this scale includes: "Sometimes a passing thought will seem so real that it frightens me." Originally developed to study hallucinatory predisposition in male and female inmates (Launay & Slade, 1981), the Launay-Slade Hallucination Scale (LSHS) is now the most widely used measure of hallucination proneness (Moseley, Smailes, Ellison, & Fernyhough, 2016; Jones & Fernyhough, 2009; Vercammen & Aleman, 2010). Since its development, the LSHS has helped to identify a number a characteristics of hallucination-prone individuals, including specific metacognitions and mental imagery.

Certain metacognitions have been linked to hallucination proneness. Positive beliefs about hearing voices have been shown to be a predictor of increased hallucination proneness and frequency in a non-clinical sample, as these individuals were more likely to welcome further engagement with the hallucinations (Morrision, Wells, & Nothard, 2002). Additionally, belief in the uncontrollable nature of thoughts and danger that may be associated with these thoughts has also been linked to high hallucination proneness (Larøi & Van der Linden, 2005). If an individual is unable to control his/her own thoughts, then the thoughts might be perceived as coming from somewhere/ someone else and the individual no longer "owns" the thought (Benjamin, 1997). As individuals began to believe the hallucinations were uncontrollable, unpredictable, and dangerous, this newfound distress subsequently increased the risk of moving further along the continuum and developing a psychopathological disorder (Stainsby & Lovell, 2014). Therefore, metacognitions concerning hallucinatory experiences may lead to an individual to be more or less prone to hallucinations.

A second factor linked to greater hallucination proneness is the vividness of the mental imagery experienced. Research has shown that simply imagining either a smell or a picture is more vivid in the minds of those who hallucinate (Arguedas, Stevenson, & Langdon, 2012; Brébion, Ohlsen, Pilowsky, & David, 2008) than those who do not hallucinate. Similarly, individuals who scored high on hallucination proneness measures also scored higher on self-report scales of mental image vividness after listening to a series of descriptive feelings, such as watching a sun set or listening to a cat (Barrett, 1993). However, there is discrepancy in the literature in that some argue that vivid mental imagery is a trait more specific to schizophrenia spectrum disorders than general hallucination proneness (Oertel et al. 2009; Sack, Van de Ven, Etschenber, Schatz, & Linden, 2005). It is possible that vivid mental imagery could account for the increased difficulty discerning between reality and fantasy that is characteristic of those with increased hallucination proneness, regardless of clinical level. It may be this difficulty in discriminating between reality and fantasy that provides the foundation for understanding normative hallucinations.

Theoretical Foundation for Hallucinations

Source monitoring theory and the effects of high stress can be used to explain the development of hallucinations. Source monitoring refers to one's ability to determine the source of a stimulus (Sugimori, Asai, & Tanno, 2010) and has often been used to illustrate cognitive dysfunctions behind hallucinations. A common illustration of source monitoring involves an individual witnessing a car run a stop sign and police questions of the event incorrectly focused around a yield sign (Loftus, 1975). The individual might be unable to determine the source of the yield sign information, and therefore might falsely remember seeing the car run a yield instead of a stop sign. In addition to being utilized in false memory research (Lilienthal, Rose, Tamez, Myerson, & Hale, 2014; Leding, 2012; Sugrue, Strange, & Hayne, 2009), source monitoring theory is also instrumental in explanations of reality monitoring (Sugimori et al., 2010). The ability to distinguish between internal (thoughts) and external (outside stimuli) is utilized on a daily basis. For instance, reality monitoring is used when one recognizes a song is playing on the radio, instead of in one's head. Moreover, source monitoring ability is affected by a number of factors, including age, working memory, hallucinations proneness, and stress.

Source monitoring ability develops and changes over time, starting at a very young age, and changes as cognitive abilities develop; in fact, one's source monitoring ability mirrors the rise and fall of an individual's cognitive abilities (Bright-Paul, Jarrold, & Wright, 2008; Earhart & Roberts, 2014; Henkel, Johnson, & De Leonardis, 1998). For instance, a study by Earhart and Roberts (2014) showed that a child at the age of 4 has significantly more trouble determining the source of a stimulus than a child at the age of 8. When presented with photographs from two separate stories, younger children displayed far more difficulty determining the original source of the photographs than older children. The authors argue that this change can be attributed to increased cognitive functioning, such as through the development of theory of mind, or the ability to recognize and attribute mental states to others that are different from one's own. This ability to distinguish between our own mental states and those of others has been linked directly to an increase in source monitoring ability, perhaps because they share a relationship with higher order thinking and reflection on one's own thoughts (Bright-Paul, Jarrold, & Wright, 2008). Conversely, as a person reaches late adulthood and cognitive abilities begin to decline, so does the ability to monitor sources. For example, a study by Henkel, Johnson, and De Leonardis, (1998) showed that adults 74 years of age displayed more difficulties during a source monitoring task than adults 20 years of age. The authors suggested that this decline in source monitoring ability might be due to a decline in the ability to differentiate between similar memories. Difficulty in discriminating between similar memories can therefore affect one's recollection of where the memory originated (i.e., the memory's source). Throughout the lifespan, cognitive processes and executive functioning dictate source monitoring ability.

A second factor that impacts source monitoring is working memory, or the capacity to hold and process information immediately in one's mind (Lilienthal et al., 2014). Working memory allows for the ability to identify and remember a stimulus' source. For instance, individuals with high working memory capacity are able to focus on and remember original stimuli, and are therefore less susceptible to errors caused by misleading stimuli or the presentation of false information (Leding, 2012). In contrast, individuals with low working memory capacity often have increased difficulty in source monitoring (Lilienthal et al., 2014). This increased difficulty is due to interference between the memories for different stimuli, meaning that an individual with low working memory capacity struggles to distinguish between sources. Therefore, one's memory for a stimulus's source is directly linked to the ability to monitor and distinguish sources.

Regardless of age and working memory capacity, individuals prone to hallucinations display difficulties discriminating between internal thoughts or mental images and external sources. In turn, such individuals have increased difficulty determining what is actually present in the physical world and what is coming from within their own minds. For example, one might think negative thoughts about oneself, but because of his or her difficulty in monitoring the source, the individual might misattribute the thought to an external voice. People with high levels of hallucination proneness have been shown to attribute their internal thoughts to an external source more often than those with low levels of hallucination proneness (Sugimori et al., 2010). Additionally, when presented with pictures and words describing objects, patients with a diagnosis of schizophrenia and high hallucination proneness incorrectly remembered seeing words as pictures more often than those without schizophrenia (Brébion et al., 2008), a finding that was repeated with odors and olfactory hallucinations (Arguedas et al., 2012). Collectively, these studies suggest that source monitoring errors offer a cognitive context under which hallucinations can be understood.

Although hallucinations can be understood in terms of difficulties individuals experience in determining sources of information, stress also plays an instrumental role in the development of hallucinations. Stress has been shown to affect source monitoring, and the effect of stress varies depending on the intensity of the stressor (Smeets et al., 2006; Strange & Takarangi, 2015b). In the case of acute stress, source monitoring ability actually increases, perhaps due to hypervigilance and more attention paid to a stimulus's source (Smeets et al., 2006; Smeets et al., 2008). For instance, participants exposed to an acute stressor prior to a source monitoring task performed significantly better than those who were not exposed to the stressor (Smeets et al., 2006; Smeets et al., 2008). In contrast, exposure to an extreme stressor or trauma often results in an increase in source monitoring errors (Strange & Takarangi, 2015b). It is possible that highly stressful events require more concentration and effort to focus on the many aspects of the event, therefore creating a chance for misinformation to affect an individual's memory and distort memory for the stimuli's original source. Therefore, in individuals who are hallucination prone, high levels of stress could lower source monitoring ability, causing more difficulty discerning between internal and external sources, ultimately resulting in the experience of a hallucination. This relationship between differing levels of stress, hallucinations, and source monitoring has yet to be tested empirically.

However, it is not only the effect of stressors on source monitoring that might account for hallucinations; it is also the physiological responses to stress in individuals who are predisposed to hallucinations. The hormone released in response to stress, cortisol, is instrumental in this relationship. Too much cortisol has linked to a decrease in hippocampal volume (Travis et al., 2016), an effect mirrored in the small hippocampi of patients with schizophrenia (Mondelli et al., 2009). Although the exact role of the hippocampus in hallucinations has not been identified, lesion studies have shown similar effects of hippocampal damage on the onset and development of hallucinations (Suzuki et al., 2004; Takebayashi, Takei, Mori, & Suzuki, 2002). It is possible that a similar, although less extreme, process involving stress, cortisol, and the hippocampus occurs during normative hallucinations. In fact, high stress and cortisol levels were shown to be predictive of more hallucinatory experiences in non-clinical participants compared to those with low levels of stress (Barnes, Koch, Wilford, & Boubert, 2011; Jones & Fernyhough, 2009). However, there is limited literature regarding the connection between stress and normative hallucinations. It would be beneficial to investigate this relationship in the context of frequently occurring normative hallucinations. Research on phantom notifications provides such a context.

Phantom Notifications

Perhaps the best example of normative hallucinations is that of phantom cell phone notifications. Phantom vibration syndrome occurs when an individual hears or feels a cell phone notification, when in fact he/she did not receive one. Both phantom vibration and phantom ringing have been investigated, although phantom vibrations are thought to occur more frequently (Tanis et al., 2015). Eighty-two percent of the population at large has reported experiencing a phantom notification (Tanis et al., 2015), suggesting that a majority of the population experiences these normative hallucinations. As such, phantom notifications offer a unique context in which to study normative hallucinations, due to their high degree of prevalence. To further understand phantom vibration syndrome as a normative hallucination, it is important to understand the different predictors of this syndrome and its link to problematic cell phone use.

Although research on the topic is limited, a number of predictive characteristics of phantom vibration syndrome have been identified. One characteristic is the desire for popularity (Tanis et al., 2015). It is possible that individuals who feel the need to be popular engage in more cell phone communication to appraise and maintain their social status, and therefore are at increased risk for experiencing phantom notifications. The trait of conscientiousness was also related to phantom vibration syndrome, with higher levels of conscientiousness being related to a lower frequency of phantom notifications (Drouin, 2012). High levels of conscientiousness may be related to being more attuned to current surroundings, and therefore less likely to experience a phantom notification. Similarly, those with higher levels of depression (Lin, Chen, Li, & Lin, 2013) and attachment anxiety (Kruger & Djerf, 2016) also exhibited more frequent phantom notifications, perhaps due to aberrant cognitive processing of information regarding emotions and interpersonal relationships, or perhaps due to hypervigilance caused by anxiety. Although a number of predictive personality characteristics have been linked to phantom vibration syndrome, it may be that individual differences regarding stress and problematic phone use may be better predictors of these experiences.

Previous studies have suggested a link between stress and phantom vibration syndrome; however, no study to date has directly measured stress. Instead, studies have used indirect measures, such as time points during a medical internship or measures of occupational burnout, as a proxy for stress. For instance, in a longitudinal study of medical interns, measures of phantom notification frequency were taken before the start of the medical internship, three time points during the internship, and two weeks after the end of the internship (Lin, Lin, Li, Huang, & Chen, 2013). As the internship began, the frequency and prevalence of phantom notifications increased with each time-point, peaked at the third week of the internship (noted by the authors to be the most stressful period of the internship), and decreased each time-point thereafter. The rise and fall of phantom notifications in relation to the point in the internship was interpreted to be due to the different stress levels of each semester point, although this interpretation was speculative, as stress was not directly measured. A connection between occupational burnout and phantom vibration syndrome has also been found (Chen, Wu, Change, & Lin, 2014). Participants who scored higher on a measure of occupational burnout also reported experiencing more phantom notifications, suggesting that stress is involved, but once again stress was not directly measured. Despite the lack of empirical studies that investigated stress directly, the anecdotal evidence provided by the studies described suggest there is a link between stress and phantom notifications.

In addition to stress, problematic phone use and emotional investment caused by phone addiction, or extreme dedication and compulsive attending to one's phone (Gutiérrez, Rodriguez de Fonsesca, & Rubio, 2016), may also account for an individual's experience of phantom notifications (Tanis et al., 2015). Problematic cell phone use itself has been associated with depressive symptoms and anxiety (Lu et al., 2011), as well as emotional instability and chronic stress (Augner & Hacker, 2011). However, it is not simply the use of a phone that is linked to depression, stress, or anxiety, but rather the extent to which an individual is emotionally invested and involved with the phone. Harwood, Dooley, Scott, and Joiner (2014) investigated the connections between phone use and mental health issues and found that the level of smart phone use did not predict depression or stress, but that high levels of emotional involvement with the phone did predict high levels of depression and stress. It is possible that phantom vibration syndrome may occur as a result of constant use of the cell phone in those who have phone addiction (Yen, Ko, Yen, Wu, & Yang, 2007). For instance, constant expectations and an emotional need to receive notifications that stems from phone addiction might increase the chance of a source monitoring error, and therefore a phantom notification. The present study expands the knowledge base about phantom notifications and problematic phone habits.

The Present Study

The present study explored normative hallucinations as manifested in phantom phone notifications, specifically by investigating potential predictors of phantom vibration syndrome and addressing gaps found in the phantom vibration and normative hallucination literature. One's source monitoring ability, combined with problematic cell phone use, stress, and a predisposition to hallucinate, could predict the occurrence and frequency of phantom vibration syndrome (see Figure 2). For instance, source monitoring errors provide an explanation for how phantom notifications occur. These errors might be more likely to happen if someone is constantly thinking of the same topic, creating more of a chance that the memory for the thought's source is misattributed to an external source. In the case of problematic phone use, phone addiction or excessive use provides a context in which source monitoring errors might increase due to monopolizing thoughts focused around the cell phone. If an individual constantly thinks about his or her phone, the probability of experiencing a source monitoring error, and therefore a hallucination, increases. Additionally, the curvilinear relationship between source monitoring and stress illustrates at which point these errors are most likely to occur. Individuals with moderate stress might be hypervigilant, therefore decreasing the likelihood of a source monitoring error and phantom notification. On the other hand, individuals with high stress might have trouble focusing on the original source of the thought, therefore increasing the likelihood of a source monitoring error and phantom notification.

In addition to the role of source monitoring, if phantom notifications are manifestations of normative hallucinations, then participants who are more predisposed to experience hallucinations should be more predisposed to experience phantom notifications. The role of stress in this relationship once again provides an explanation of when these hallucinations are most likely to occur, suggesting that high stress might increase the likelihood of experiencing a phantom notification.

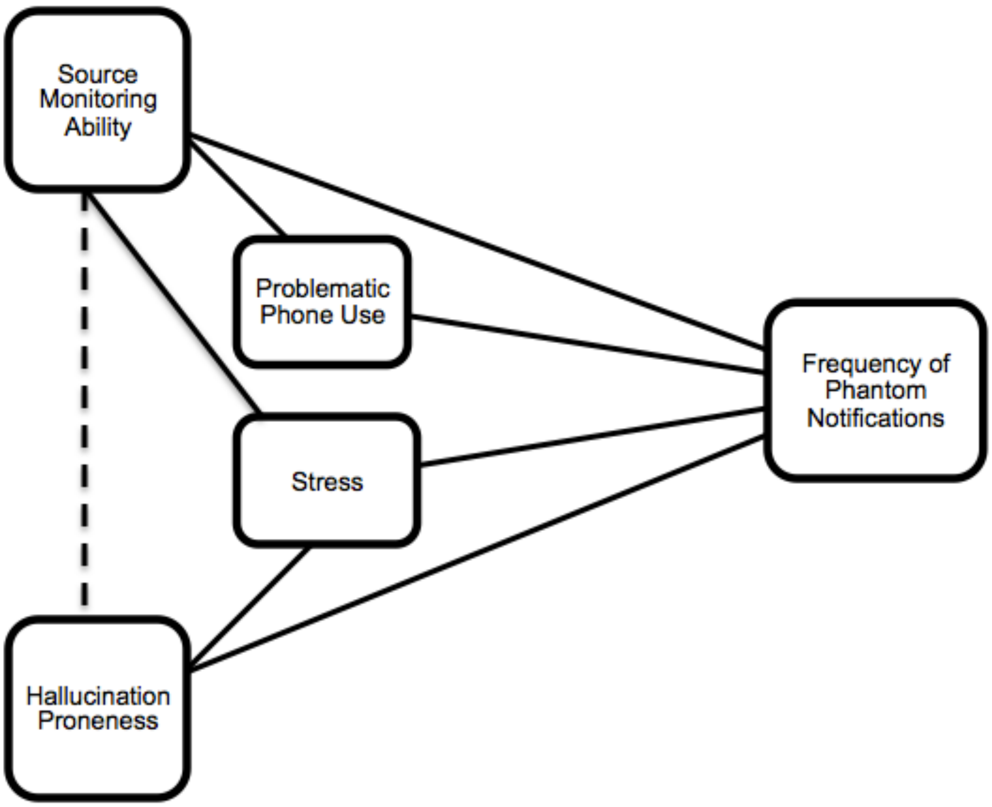

Figure 2. The model for the present study involves a direct relationship between source monitoring ability/ hallucination proneness and the frequency of phantom notifications. Additionally, these relationships are moderated by problematic cell phone use and stress. The solid lines represent relationships directly tested by hypotheses, whereas the dashed line represents a relationship that has already been suggested by the literature and therefore is not reflected in the hypotheses.

The hypotheses for the current study were as follows:

1. Source monitoring deficits would predict phantom vibration syndrome, in that lower scores on the source monitoring task would be associated with more frequent phantom notifications.
2. Problematic cell phone use would moderate the relationship between source monitoring ability and phantom vibration syndrome, specifically that source monitoring ability would predict more frequent phantom notifications in individuals with high levels of problematic cell phone use, but not when individuals report low levels of problematic cell phone use.
3. Stress level would moderate the relationship between source monitoring ability and phantom vibration syndrome. Source monitoring ability would predict less frequent phantom notifications in individuals who report moderate levels of stress, whereas in individuals who report either low or high stress, source monitoring ability would predict more frequent phantom notifications.
4. Hallucination proneness would predict phantom vibration syndrome, in that higher levels of hallucination proneness would predict a higher frequency of phantom notifications.
5. Stress would moderate the relationship between hallucination proneness and phantom vibration syndrome, specifically that hallucination proneness would predict a higher number of phantom notifications if the individual reports high stress levels, but not when the individual reports lower stress levels.

Method

Participants

Two hundred and nine participants were recruited through the undergraduate Human Participant Pool (HPP) at a Southern California university. The inclusion of undergraduate students was beneficial to this study due to the high prevalence of hallucinatory experiences in adolescents and young adults (Johns & van Os, 2001), as well as the frequent use of cell phones and other technologies in the age group (Harwood et al., 2014). As such, participation in the study was limited to individuals under the age of 30 in order to ensure a sample of only young adult undergraduates. Seven participants reported they were 30 years old or older, and were thus removed from the analyses. One additional participant was unable to complete the study due to computer issues, yielding a final sample of 201 participants. The mean age of the sample was 20.12 (*SD* = 2.30) years and 67.2% of the participants were female. Additionally, 43.8% identified as Hispanic, 23.9% identified as White, 11.4% identified as Asian, 6% identified as African American, and 11% identified as "Other". Informed consent was obtained prior to the start of the study and all participants received one unit of HPP course credit for participation.

Procedure

The proposed study utilized a modified procedure similar to a study conducted by Hashtroudi, Johnson, and Chronsniak (1989). Upon arrival, participants were randomly assigned to one of the counterbalanced groups and informed consent was obtained before beginning the study. The study was divided into four phases: practice, acquisition, test, and survey. Each participant was presented with a series of words: for half of the words, the participant was instructed to imagine repeating the word and for the other half of the words, the participant was instructed to listen to the researcher repeat the word. First, the researcher conducted a brief practice round with the participant, instructing the participant to imagine repeating and to listen to the researcher repeat a number of words. At the end of the practice round, the researcher asked the participant for a description of what the participant thought of when imagining the words. If the participant reported that he or she thought of the object (for example, a hat), the researcher emphasized the importance of imagining *hearing* the word, instead of the actual object the noun represents. The researcher asked the participant to confirm if he or she understood the clarified instructions.

Once the participant replied that he or she understood the instructions, the researcher began the acquisition phase. The acquisition phase consisted of the researcher reading the series of 30 target words at a rate of 4 seconds per word, with each word accompanied by an instruction to either imagine (15 words) or listen (15 words) to the word being repeated. After all target words were read, the researcher presented the participant with the surprise, untimed memory test consisting of 60 words: all 30 targets and 30 distractors. For each word, the participant indicated if he or she either imagined repeating the word, listened to the researcher repeat the word out loud, or if the word was a new word that was not previously presented. During the testing phase, all 60 words were presented in random order, and it was ensured that no two words that were presented in sequence in the acquisition phase were presented in sequence in the test phase. The words were counterbalanced across participants, so that each word appeared as an imagined word, listened word, and as a distractor for the memory test.

Upon completion of the memory test, the participant was then instructed to complete the survey of self-report measures. When the participant completed the self-report survey, the researcher partially debriefed the participant.

Measures

Source monitoring. Source monitoring was assessed using a source monitoring task created by Hashtroudi et al. (1989). A total of 60 nouns were randomly chosen from a list of words developed by Thorndike and Lorge (1944). Each noun was indicated as occurring between 30-40 times per million.

A source monitoring score was calculated by first adding the participant's total number of words correctly identified as *imagined* and correctly identified as *listened*. This number was then divided by the total number of words correctly remembered as being previously presented during the acquisition phase. Higher source monitoring scores indicated better source monitoring ability. A similar scoring method had been used previously (Foley, Johnson, & Raye, 1983) and is beneficial because it focuses directly on memory for the stimuli's correct source instead of memory for the item. Validity of this score was shown by its ability to detect age-related differences in source monitoring that is found throughout the literature (Hashtroudi et al., 1989; Henkel et al., 1998). Results of the present study yielded a mean source monitoring score of 0.63 (*SD* = 0.14).

Problematic phone use. Two subscales identified by Tanis et al. (2015), phone addiction and excessive phone use, from the *Text Message Dependency* scale originally created by Igarashi, Motoyoshi, Takai, and Yoshida (2008) were combined and used to measure problematic phone use. Participants rated items from both subscales using a 7-point Likert scale (*1 = strongly disagree; 7 = strongly agree*), with higher scores indicating higher levels of problematic phone use. The subscale of phone addiction consists of 15 statements; a sample question from this subscale is: "My productivity has decreased as a direct result of the time I spend on the cell phone." Tanis et al. (2015) reported a Cronbach alpha of .93. The 4-item subscale of excessive phone use was also used. A sample item is: "I use messages even while I am talking with friends." The authors report a Cronbach alpha of .85 (Tanis et al., 2015). Validity of the original scale is supported by a significant relationship to addictive behaviors, as assessed by its relationship with questions from the DSM-IV substance dependency criteria (Igarashi et al., 2008). The present sample's combined problematic phone use score had a mean of 3.06 (*SD* = 0.84) and showed good internal consistency, with a Cronbach alpha of .85.

Perceived stress. Cohen and Williamson's (1988) Perceived Stress Scale-10 was used to measure the construct of perceived stress. This measure consisted of 10 questions rated on a 5-point Likert scale (*0 = never; 4 = very often*); higher scores indicate higher levels of perceived stress. A sample question from this measure is: "In the last month, how often have you felt nervous and stressed?" Previous studies have yielded Cronbach alphas between .78 (Cohen & Williamson, 1988) and .89 (with undergraduate students; Roberti, Harrington, & Storch, 2006). Evidence for this scale's validity was found with its positive association with anxiety, as assessed by the total State-Trait Anxiety Inventory score (Roberti et al., 2006). The present study's mean perceived stress score was 1.83 (*SD* = 0.73), and displayed good internal reliability (Cronbach α = .88).

Hallucination proneness. Hallucination proneness was measured by a modified version of the Launay-Slade Hallucination Scale- Revised (LSHS-R; Launay & Slade, 1981). The final LSHS-R used in this study consisted of 10statements each rated on a 4-point Likert scale (*1 = certainly does not apply to you; 4 = certainly does apply to you*), with higher scores indicating a higher level of hallucination proneness. An example question from this scale is: "In the past, I have had the experience of hearing a person's voice and then found that no one was there." Validity of the LSHS-R is supported by significant correlations with symptoms of schizotypy and borderline personality disorder, as assessed with both the Schizotypy Trait Questionnaire and the Borderline Traits Scale (Goodarzi, 2009). For the purpose of this study, three questions were removed from the original scale because it was thought that these questions might elicit response bias in the participants due to the nature of the questions. An example of one of the questions that was removed is: "I have never heard the voice of the Devil."

An extra question regarding the experience of tactile hallucinations was also added to this measure. This extra question was taken from another modified version of the LSHS-R by Laroi, Marczewski, and Van der Linden (2004) that sought to encompass the many possible modalities of hallucinatory experiences. The question taken from this modified scale was: "I have had the feeling of touching something or being touched and then found that nothing or no one was there." The purpose of adding this question was to ensure tactile hallucinations were addressed due to the present study's focus on vibrations. Results from the present study indicated that the reliability of the measure was considered high (Cronbach α = .82). Additionally, the scale yielded a mean hallucination proneness score of 2.01 (*SD* = 0.61).

Phantom notifications. The presence of phantom notifications was assessed by nine self-report questions created by the author for this study. Six of the self-report questions were open-ended regarding the occurrence and frequency of phantom notifications throughout the previous day, the day before yesterday, and in the last week, and concerned vibrations, ringing, and the blinking of the phone's screen to indicate notifications. A sample question was: "In the past week, how many times did you check your phone after feeling it vibrate, only to realize it did not vibrate?" Higher numbers of reported phantom vibrations, ringing, or blinking indicate more frequent phantom notifications. Three additional 9-point Likert scale questions regarding the frequency of phantom vibrations, ringing, and blinking were used (*1 = never; 9 = several* *times an hour*), with higher scores on these questions indicating a higher frequency of phantom notifications. An example of the Likert-type questions was: "In general, how often do you think your phone vibrated, but it did not?"

After investigating the distributions and skew of all nine variables, it was found that the open-ended questions were highly positively skewed. As such, the three Likert-scale questions were then combined into a new phantom notification scale, with a mean of 4.30 (SD = 2.10) and demonstrated good internal consistency (Cronbach $\alpha = .72$). This phantom notification scale was then used in all analyses for the present study to measure the frequency of phantom notifications.

Power and Planned Analyses

A power analysis was conducted to determine the number of participants needed to obtain statistical power of at least .80 at a significance level of .05 (two-tailed).

Hypothesis 1: Source monitoring ability and phantom notifications. There have been no studies that investigate the relationship between source monitoring ability and the frequency of phantom notifications. As such, a small-medium effect size was predicted. A correlation was conducted to address the hypothesis that poorer source monitoring ability would be linked to more frequent phantom notifications. Using G*Power 3.1, it was determined that in order to obtain adequate statistical power for $r = .20$ at a .05 level of significance, 193 participants were needed for this analysis (Faul, Erdfelder, Buchner, & Lang, 2009).

Hypothesis 2: Problematic phone use as a moderator. Tanis et al. (2015) investigated the relationship between phantom vibration syndrome and problematic phone use, and found that phantom vibration syndrome was significantly correlated to both phone addiction ($r(401) = .38$, $p < .05$) and excessive use ($r(401) = .42$, $p < .05$), indicating medium and medium-large effects, respectively (Cohen, 1992). Additionally, no study to date had investigated problematic phone use and source monitoring ability. Prior to directly addressing the hypothesis, bivariate relationships were investigated using correlations. In order to test the hypothesis that problematic phone use moderated the relationship between source monitoring ability and phantom notifications, a linear regression was conducted with three variables (source monitoring score, problematic phone use score, and the interaction between these variables). Thus, a medium effect size was estimated for the main effect of this relationship, whereas a small-medium effect was estimated for the interaction. Based on the small-medium effect predicted for the interaction, to reach adequate power at a .05 level of significance for $f^2 = .04$, a sample of 199 participants was needed (Faul et al., 2009).

Hypothesis 3: Perceived stress as a moderator with source monitoring ability. Smeets et al. (2008) conducted a study on the effects of acute stress and internal-external source monitoring ability using a cold pressor task. Results of the study indicated that participants in the stress condition performed significantly better than participants in the control condition ($t(78) = -6.31$, $p < .001$, $d = 1.43$) indicating a large effect size. Although source monitoring ability has not been directly studied in relation to high stress, false memory research can be used in lieu of source monitoring (Strange & Takarangi, 2015a). Zoellner, Foa, Brigidi, and Przeworski (2000) investigated differences in false memories for participants who were exposed to trauma and those who were not exposed to trauma. Results from the study indicated that the participants who were exposed to trauma were more susceptible to false memories, and therefore were susceptible to errors in source monitoring ($F(2, 38) = 3.70$, $p < .05$, $r = .47$) suggesting a medium-large effect. Before examining the hypothesis, bivariate relationships were examined using correlations. To address the hypothesis that stress would moderate the relationship between source monitoring ability and phantom notifications, a linear regression was conducted with three variables (source monitoring score, stress score, and the interaction). Based on previous studies yielding an average medium effect size, it was predicted that the main effects for the relationship would be a medium effect, whereas the interaction would be a small-medium effect. In order to obtain adequate power for the interaction of $f^2 = .04$ at a significance level of .05, a total of 199 participants were needed (Faul et al., 2009).

Hypothesis 4: Hallucination proneness and phantom notifications. To date, there have been no studies regarding the relationship between hallucination proneness and phantom notifications. Therefore, it was estimated that this relationship will yield a small-medium effect size. To address the hypothesis that higher hallucination proneness would be linked to more frequent phantom notifications, a correlation was conducted. In order to obtain a statistical power of .80 for $r = .20$ at a significance level of .05, 193 participants were needed for this analysis (Faul et al., 2009).

Hypothesis 5: Perceived stress as a moderator with hallucination proneness. Although there have been no studies to date that have looked at the link between stress and phantom notifications directly, a study by Chen and colleagues (2014) has linked occupational burnout to phantom notifications. Chen et al. (2014) found that personal fatigue (odds ratio = 1.03, $p < .001$) and job fatigue (odds ratio = 1.03, $p < .001$) were significantly related to phantom vibrations. Using occupational burnout as a type of stress, these results indicate a small effect. Additionally, Jones and Fernyhough (2009) conducted a study on the relationship between stress and hallucination proneness using a non-clinical, university student sample. Results of this study showed that stress was a significant predictor of phantom vibration syndrome ($b = .42$, $p < .001$) and also explained a significant portion of the variance in phantom vibration syndrome ($R^2 = .18$,

$F(3, 215) = 15.35$, $p < .001$). These results indicate that there was a medium effect. Bivariate relationships were first examined using correlations. In order to test the present hypothesis that stress would moderate the relationship between hallucinations proneness and phantom notifications, a linear regression with three variables (hallucination proneness score, stress score, and the interaction) was conducted. Based on the previous studies reviewed, it was estimated that a medium effect size would be seen for the main effects and a small effect size would be seen for the interaction. G*Power ($f^2 = .04$ for the interaction effect) yielded a sample size of 199 participants to reach adequate power (Faul et al., 2009).

Pilot Study

A pilot study was conducted to investigate the psychometric properties of the measures used in the study and to test the study's procedure. Participants ($N = 20$) were recruited through a university in southern California. The mean age of the participants was 21.5 ($SD = 5.27$) years, 80% were female, 45% identified as White, and 30% identified as Hispanic. The materials and procedure in the pilot study were identical to the proposed methods of the present study, with two exceptions: the blinking of a phone's screen as a type of phantom notification and questions concerning the number of phantom notification experienced the day before yesterday were not initially included. Results regarding the psychometric properties of the materials chosen indicated that the LSHS-R ($M = 1.98$, $SD = .68$, Cronbach $\alpha = .88$), Perceived Stress Scale ($M = 2.79$, $SD = .59$, Cronbach $\alpha = .87$), and the Problematic Phone Use Scale ($M = 3.01$, $SD = 0.99$, Cronbach $\alpha = .89$) all displayed high internal consistency. The mean source monitoring score was .68 ($SD = .14$), which was lower than that found in Hashtroudi et al.'s (1989) study of participants with a comparable age ($M = .89$, $SD = .10$); however, variability was seen in the pilot study, with scores ranging from .44 to .96. A Kuder-Richardson 20 analysis was conducted to evaluate the reliability of the source monitoring task, yielding an adequate reliability statistic of .73. Additionally, a one-way ANOVA was conducted to investigate the effectiveness of counterbalancing the target and distractor words. Words were counterbalanced both in terms of order and in terms of the frequency each word occurred as a target (either imagined or listened) and as a distractor. No significant difference was found in source monitoring scores between any of the counterbalancing groups ($F(3, 16) = .20$, $p = .89$, $\omega^2 = -.13$) suggesting that there was not an effect of the words used or the order of the words presented.

Reports of phantom vibrations in the previous day (*M* = 1.28, *SD* = 1.48) and in the past week (*M* = 3.68, *SD* = 4.22) were higher than reports of phantom ringing, both for the previous day (*M* = .33, *SD* = .61) and the past week (*M* = 1.53, *SD* = 1.52). With regards to the frequency of phantom notifications overall, the Likert-type questions concerning phantom notifications indicated that phantom ringing had a mean score of 2.35 (*SD* = 1.76) and phantom vibrating had a mean score of 3.90 (*SD* = 2.27). Collectively, these data suggest that the proposed measures exhibit acceptable psychometric properties for use in these analyses.

Results

Preliminary Analyses

Data were examined prior to commencing hypothesis testing. Examination of study variables revealed no univariate outliers. The distributions and violations of normality were checked for the variables of source monitoring score (skewness = -0.18, *SE* = 0.17, kurtosis = -0.45, *SE* = 0.34), problematic phone use (skewness = 0.29, *S*E = 0.17, kurtosis = -0.01, *SE* = 0.34), perceived stress (skewness = -0.08, *SE* = 0.17, kurtosis = -0.40, *SE* = 0.34), hallucination proneness (skewness = 0.40, *SE* = 0.17, kurtosis = -0.46, *SE* = 0.34), and phantom notifications (skewness = 0.34, *SE* = 0.17, kurtosis = -0.75, *SE* = 0.34) and were found to all be normally distributed. Five multivariate outliers were detected using Mahalanobis distances evaluated at $p < .001$. Analyses were run with and without these participants included; omission of these participants did not affect the results of subsequent analyses, so all participants were retained in the analyses.

For the first preliminary analysis, differences between the four counterbalanced word lists for the source monitoring task were examined. A one-way analysis of variance was conducted and indicated that there were no differences across word lists ($F(3, 196) = 2.26$, $p = .08$); subsequently, all groups were combined for further analyses. Additionally, any differences between the three researchers who conducted the source monitoring task were investigated. A one-way analysis of variance was conducted, yielding no significant differences in source monitoring score between researchers ($F(2, 197) = .73$, $p = .48$), so all data were combined across researchers.

Finally, bivariate relationships were examined among the major study variables (see Table 1 for correlation results).

Table 1

Results of Bivariate Correlations Between All Studied Variables

	Phantom Notifications	Source Monitoring Score	Problematic Phone Use	Perceived Stress	Hallucination Proneness
Phantom Notifications	-	-	-	-	-
Source Monitoring Score	-.01	-	-	-	-
Problematic Phone Use	.36***	.05	-	-	-
Perceived Stress	.25***	.06	.32***	-	-
Hallucination Proneness	.20**	.13	.19**	.35***	-

* $p < .05$
** $p < .01$
*** $p < .001$

Hypothesis Testing

The first hypothesis predicted that source monitoring ability would be related to the frequency of phantom notifications, in that lower source monitoring scores would be related to higher frequencies of phantom notifications. In order to test this prediction, a Pearson product-moment correlation was conducted between source monitoring score and the frequency of phantom notifications. Results failed to support the hypothesis: source monitoring ability was not related to the frequency of phantom notifications ($r(198) = -.01$, $p = .95$).

The second hypothesis considered problematic phone use as a moderator of the relationship between source monitoring ability and phantom notifications. It was hypothesized that problematic phone use would moderate the relationship between source monitoring ability and phantom notifications such that the relationship between source monitoring ability and phantom notification would be higher for individuals with higher levels of problematic phone use compared to individuals with lower levels of problematic phone use. The variables were first examined for suitability in multivariate analyses. The assumptions of linearity, normality, and homoscedasticity were met for multiple linear regression analyses; however, when the interaction between source monitoring score and problematic phone use was entered into the model, the assumption of multicollinearity was violated, shown by high variance inflation factors (between 12.01 and 30.75) and low collinearity tolerance statistics (between 0.03 and 0.08). To address multicollinearity, the predictor variables were centered prior to completion of the analysis, which effectively addressed the multicollinearity. The frequency of phantom notifications was regressed onto source monitoring and problematic phone use, as well as the interaction between them. Overall, the model accounted for 14% of the variance in the frequency of phantom notifications ($F(3, 196) = 10.69$, $p < .001$; see Table 2). There was a significant direct effect of problematic phone use itself ($b = 0.86$, $SE = 0.17$, $p < .001$, CI [0.53, 1.19]), indicating that regardless of source monitoring ability, higher problematic phone use predicts a higher frequency of phantom notifications. However, contrary to the original hypothesis there was no significant interaction effect, indicating that problematic phone use does not moderate the relationship between source monitoring score and phantom notifications ($b = 1.86$, $SE = 1.06$, $p = .08$, CI [-0.24, 3.95]).

Table 2

Summary of the Relationship Between Source Monitoring Score and Problematic Phone Use Regarding the Frequency of Phantom Notifications (N = *200*)

Variable	*B*	*SE B*	*β*
Source Monitoring Score	-0.36	0.98	-0.02
Problematic Phone Use	0.86	0.17	0.34***
Source Monitoring Score x Problematic Phone Use	1.86	1.06	0.12
R^2		.14	
F		10.69***	

Note: Source monitoring score and problematic phone use were centered around their means.

* $p < .05$
** $p < .01$
*** $p < .001$

The third hypothesis predicted that perceived stress would moderate the relationship between source monitoring ability and phantom notifications such that source monitoring ability would be predictive of less frequent phantom notifications in individuals with moderate levels of perceived stress. In order to test this effect, the frequency of phantom notifications was regressed onto perceived stress and source monitoring ability, and their interaction. Due to the curvilinear relationship of the hypothesis, perceived stress was trichotomized into three equal groups based on score: low (scores 0-1.33), moderate (scores 1.34-2.67), and high perceived stress (scores 2.68-4). Following the procedure outlined by Hayes (2015) for categorical moderators with three levels, the Hayes (2013) PROCESS macro for SPSS was used to conduct the regression analysis. In this procedure, low and high perceived stress were dummy coded, utilizing moderate perceived stress as the comparison group. Overall, the model significantly accounted for 6% of the variance in phantom notification frequency, ($F(5, 194) = 2.46$, $p = .03$; see Table 3). There was not a direct effect of source monitoring score ($b = -0.24$, $SE = 1.39$, $p = .86$, CI [-2.98, 2.50]). Perceived stress level also did not appear to be a significant moderator of the relationship between source monitoring ability and phantom notifications, as the effect of source monitoring ability on phantom notifications did not differ between low and moderate perceived stress ($b = -1.76$, $SE = 2.34$, $p = .45$, CI [-6.36, 2.85]) or high and moderate perceived stress ($b = 3.21$, $SE = 3.48$, $p = .36$, CI [-3.65, 10.06]). Additionally, the R^2 change due to both interactions was not significant ($F(2, 194) = 0.93$, $p = .40$), and source monitoring score did not appear to have a conditional effect on phantom notifications at moderate perceived stress levels ($t(199) = -0.17$, $p = .86$). As such, the hypothesis that perceived stress moderates the relationship between source monitoring ability and phantom notifications in a curvilinear manner was not supported.

Table 3

Summary of the Curvilinear Relationship Between Source Monitoring Score and Perceived Stress Regarding the Frequency of Phantom Notifications (N = *200*)

Variable	*B*	*SE B*
Source Monitoring Score	-0.24	1.39
Low Perceived Stress	0.39	1.46
Source Monitoring Score x Low Perceived Stress	-1.76	2.24
High Perceived Stress	-1.05	2.24
Source Monitoring Score x High Perceived Stress	3.21	3.48
R^2	.06	
F	2.46*	

* $p < .05$
** $p < .01$
*** $p < .001$

Further exploratory analyses were conducted to investigate if perceived stress and source monitoring score had a linear, as opposed to curvilinear, relationship to problematic phone use. The frequency of phantom notifications was regressed on perceived stress and source monitoring, as well as the interaction between them. The new model accounted for 7.1% of the variance in phantom notifications ($F(3, 196) = 5.02$, $p = .002$; see Table 4). There was a significant direct effect of perceived stress ($b = 0.76$, $SE = 0.20$, $p < .001$, CI [0.37, 1.16]), suggesting that regardless of source monitoring score, perceived stress was linearly predictive of phantom notifications in that a higher perceived stress level predicted a higher frequency of phantom notifications. Additionally, there was no significant interaction effect (b = 1.15, SE = 1.41, p = .42, CI [-1.64, 3.93]), suggesting that perceived stress does not moderate the relationship between source monitoring and phantom notifications.

Table 4

Summary of the Linear Relationship Between Source Monitoring Score and Perceived Stress Regarding the Frequency of Phantom Notifications (N = *200*)

Variable	*B*	*SE B*	β
Source Monitoring Score	-0.15	1.03	-0.01
Perceived Stress	0.76	0.20	0.26***
Source Monitoring Score x Perceived Stress	1.14	1.41	0.06
R^2		.07	
F		5.02**	

Note: Source monitoring score and perceived stress were centered around their means.

* $p < .05$
** $p < .01$
*** $p < .001$

The fourth hypothesis predicted that higher scores on the hallucination proneness measure would be related to more frequent phantom notifications. In order to test this relationship, a Pearson product-moment correlation was conducted. Results indicated that hallucination proneness was significantly related to the frequency of phantom notifications

($r(199) = .20$, $p = .01$). These data suggest that as an individual's hallucination proneness score increases, so does their frequency of phantom notifications.

To further examine the relationship between hallucination proneness and phantom notifications, the moderating effect of perceived stress was investigated in an analysis of the fifth hypothesis. It was predicted that perceived stress would have a linear effect on the relationship between hallucination proneness and phantom notifications, in that hallucination proneness would be predictive of more phantom notifications in individuals who also have high levels of perceived stress. The assumptions of linearity, normality, and homoscedasticity for multiple linear regression were all checked and were not violated; however, when the interaction between hallucination proneness and perceived stress was entered in the model, the assumption of multicollinearity was violated, as seen by high variance inflation factors (between 8.03 and 25.27) and low collinearity tolerance statistics (between 0.40 and 0.13). To address multicollinearity, all variables were then centered, which effectively decreased the multicollinearity. The frequency of phantom notifications was then regressed onto perceived stress and hallucination proneness, and their interaction. Overall, the model significantly accounted for 8.1% of the variance in phantom notification frequency ($F(3, 197) = 5.75$, $p < .001$; see Table 5). There was a direct effect of perceived stress itself ($b = 0.62$, $SE = 0.21$, $p = .004$, CI [0.23, 1.04]), suggesting that regardless of hallucination proneness, the more perceived stress one reported, the more frequent phantom notifications he or she experiences. However, contrary to the original hypothesis there was no significant interaction effect, suggesting that perceived stress did not moderate the relationship between hallucination proneness and phantom notifications ($b = -.03$, $SE = 0.32$, $p = .44$, CI [-0.88, 0.38]).

Table 5

Summary of the Relationship Between Hallucination Proneness and Perceived Stress Regarding the Frequency of Phantom Notifications (N = *201*)

Variable	*B*	*SE B*	*β*
Hallucination Proneness	0.46	0.26	0.13
Perceived Stress	0.62	0.21	0.22**
Hallucination Proneness x Perceived Stress	-0.25	0.32	-0.77
R^2		.08	
F		5.75***	

Note: Hallucination proneness and perceived stress were centered around their means.

* $p < .05$
** $p < .01$
*** $p < .001$

Additional Exploratory Analyses

Further analyses were conducted to explore source monitoring ability as a moderator in the relationship between hallucinations proneness and phantom notifications. The assumptions of linearity, normality, and homoscedasticity for multiple linear regression were all met; however, when the interaction between hallucination proneness and source monitoring score was entered into the model, the assumption of multicollinearity was violated, as evidenced from high variance inflation factors (between 13.60 and 42.13) and low collinearity tolerance factors (between 0.02 and 0.04). As such, the predictors were centered to address the multicollinearity, which resulted in a decrease in the multicollinearity. The frequency of phantom notifications was regressed onto source monitoring ability and hallucination proneness, and their interaction. The overall model significantly accounted for 5% of the variance in phantom notifications ($F(3, 199) = 3.54$, $p = .02$; see Table 6), but there was no significant interaction indicating that source monitoring did not moderate the relationship between hallucination proneness and phantom notifications ($b = 2.99$, $SE = 1.83$, $p = .11$, CI [-0.63, 6.60]). However, there was a direct effect of hallucination proneness itself, as hallucination proneness appeared to be a significant predictor of phantom notifications ($b = 0.64$, $SE = 0.25$, $p = .01$, CI [0.16, 1.13]). Thus, regardless of source monitoring ability, greater hallucination proneness is associated with higher frequencies of phantom notifications.

Table 6

Summary of the Relationship Between Hallucination Proneness and Source Monitoring Score Regarding the Frequency of Phantom Notifications (N = *200*)

Variable	*B*	*SE B*	*β*
Hallucination Proneness	0.64	0.25	0.19**
Source Monitoring Score	-0.41	1.04	-0.03
Hallucination Proneness x Source Monitoring Score	2.99	1.83	0.11
R^2		.05	
F		3.54*	

Note: Hallucination proneness and source monitoring score were centered around their means.

* $p < .05$
** $p < .01$
*** $p < .001$

In addition, source monitoring score, problematic phone use, perceived stress, and hallucination proneness were entered into a standard multiple linear regression to predict the frequency of phantom notifications. The assumptions of linearity, normality, homoscedasticity, and multicollinearity for multiple linear regression analyses were checked and were all met. Results indicated that the four predictors accounted for 16% of the variance in phantom notifications ($F(4, 195) = 9.20$, $p < .001$); however, when combined, only problematic phone use appeared as a significant predictor of phantom notifications ($b = 0.75$, $SE = 0.18$, $p < .001$, CI [0.40, 1.09]; see Table 7).

Table 7

Multiple Linear Regression Predicting Frequency of Phantom Notifications (N = *200*)

Variable	*B*	*SE B*	*β*
Source monitoring score	-0.61	0.98	-0.04
Problematic phone use	0.75	0.18	0.30***
Perceived Stress	0.38	0.21	0.13
Hallucination proneness	0.33	0.25	0.09
R^2		.16	
F		9.20***	

* $p < .05$
** $p < .01$
*** $p < .001$

Discussion

Phantom notifications occur when individuals feel, hear, or see that they received a cell phone notification when in fact they did not. The present study examined predictors of phantom notifications. Specifically, the roles of source monitoring ability, problematic phone use, perceived stress, and hallucination proneness were explored. Results indicated that source monitoring ability was not related to phantom notifications but hallucination proneness and problematic phone use were related to higher frequencies of phantom notifications. Moreover, whereas perceived stress did not serve as a moderator in these relationships, it did predict phantom notifications, regardless of the level of hallucination proneness. Subsequent exploratory analyses showed that problematic phone use emerged as the most predictive factor in phantom notification frequency, suggesting that the effects of cell phone use should be explored further.

Source Monitoring Ability

Source monitoring ability, or one's ability to determine the internally or externally generated source of a stimulus, was not related to either phantom notifications or hallucination proneness, contrary to what was expected. The failure to find a relationship indicates that a disruption in the process of distinguishing between internal and external stimuli is not likely the cause of phantom notifications. That is, individuals who are able to discern between thoughts about receiving a cell phone notification and actually seeing, feeling, or hearing a notification, experience phantom notifications at the same rate as those who have difficulty distinguishing between the internal and external sources. These results differ from previous studies that have linked source monitoring ability and the experience of hallucinations (Arguedas et al., 2012; Brébion et al., 2008; Sugimori et al., 2010), suggesting that there might be differences between phantom notifications and other types of hallucinations. Perhaps phantom notifications themselves are such a common hallucinatory experience that source monitoring may not be a construct that can accurately distinguish between individuals' frequency of phantom notifications. In fact, although previous reports indicate that as much as 40% of the general population reports having had normative hallucinations (Ohayon, 2000), a large majority of 83% of the sample in the present study reported experiencing phantom notifications. The large proportion of people who experience phantom notifications suggests that phantom notifications themselves are somehow different from other normative hallucinations and may be due to different causal factors. Although these interpretations may explain the current study's failure to find a connection between source monitoring and phantom phone vibrations, it is possible that the difficulty lies with the measure itself.

To measure source monitoring ability in the current study, participants listened to a series of instructions that prompted them to both imagine repeating a number of words and to listen to the researcher repeat words out loud. Afterwards, participants completed a test in which they indicated if they either imagined a word, listened to the researcher repeat a word, or if the word was a new word that was not previously presented. However, the source monitoring task used might not have measured exactly what it was intended to measure in the present study. For instance, the idea behind the original hypotheses was that individuals who experience phantom notifications have difficulty discerning between internally and externally generated sources, which is often referred to as reality monitoring (Leynes, Cairns, Crawford, 2005). The present hypotheses hinged on the assumption that individuals who have difficulty discerning between sources will have more trouble distinguishing between thoughts of cell phone notifications and actual notifications. However, source monitoring itself is essentially a memory task, measuring an individual's *memory* for internal and external sources. It is possible that a distinction exists between remembering a stimulus' source after the fact and immediately discerning between the sources. Perhaps there is something systematically different with regards to memories of sources and immediate source monitoring, which would suggest a distinction that a source monitoring task could not capture. Although previous studies have utilized similar methods to measure reality monitoring (Cooper, Plaisted-Grant, Baron-Cohen, & Simons, 2016; Humpston, Linden, & Evans, 2017; Leynes et al., 2005), perhaps this distinction between immediate discrimination of sources and source monitoring as a form of memory is more pronounced for phantom notifications due to the common nature of the phenomenon, as opposed to other types of hallucinations. As no relationship was found with source monitoring ability, results indicated that perhaps problematic phone use might be a better predictor of phantom notifications.

Problematic Phone Use

Regardless of source monitoring ability, problematic cell phone use was significantly related to phantom notifications, as expected. When considered in the context of source monitoring, hallucination proneness, and perceived stress, it was high levels of problematic phone use that was most predictive of phantom notifications. Problematic phone use has also been found to be predictive of phantom notifications in other studies (Tanis et al., 2015): it appears that being attached to one's phone makes one susceptible to increased phantom notification experiences. Previous studies have suggested that high levels of phone attachment may lead individuals to misinterpret other stimuli as phone notifications (Rothberg et al., 2010). One explanation that has been offered for this phenomenon is the called hypothesis-guided search theory (Pennebaker & Skelton, 1981). This theory posits that overwhelming sensory input causes the brain to produce illusions and/or errors by incorrectly applying schemas based on what is expected (Rothberg et al., 2010). This may be the case with phone notifications. Although very similar to the source monitoring hypothesis, which suggested that thoughts regarding the cell phone *create* phantom notifications, the hypothesis-guided search theory suggests that real stimuli are *misinterpreted* due to expectations for phone calls. For instance, stimuli such as the brush of clothing against the skin or a quiet sound in the room are misinterpreted as a phone notification when the brain automatically applies a preconceived schema or expectation that a phone notification was received. The automatic application of these preconceived schemas suggests that this process is unconscious and not able to be detected by the individual. Therefore, conscious thoughts about cell phone notifications and difficulties discerning between internally and externally generated sources might not be linked to the experience of phantom notifications. However, further research is needed to investigate the distinction between automatically applied schemas and conscious thoughts, as well as the hypothesis-guided search theory, in the context of phantom notifications. Furthermore, problematic phone use has been shown in those with high social anxiety (Sapacz, Rockman, & Clark, 2016) and low self esteem (Gutiérrez et al., 2015). It is possible that individuals with these characteristics might experience feelings of fear or worry about missing a call, which might in turn increase thoughts revolving around receiving a call. Therefore, it is more likely that a preconceived schema associated with a cell phone notification would be applied a stimulus, thus increasing the experience of phantom notifications. However, more investigation of the roles that worry, stress, or other contextual factors play in this phenomenon is warranted.

Perceived Stress

Although problematic phone use plays a large role in the experience of phantom notifications, these experiences can be further understood by examining the role of perceived stress. It was anticipated that perceived stress would prove to be an important variable in explaining relationships between source monitoring ability and hallucination proneness, and phantom notifications. These hypotheses were explored using three different models of perceived stress and the findings are discussed separately.

First, the role of perceived stress as a three-level moderator for source monitoring ability and phantom notifications was explored. It was predicted that perceived stress would have a curvilinear effect on the relationship between source monitoring ability and phantom notifications, due to previous studies that showed high stress caused a decrease in source monitoring ability (Strange & Takarangi, 2015b), whereas moderate stress caused an increase in ability (Smeets et al., 2006). In the present study, it was thought that as perceived stress reached a moderate level, the individual would reach a state of hypervigilance, which would heighten source monitoring ability and thus be related to a decrease in the frequency of phantom notifications. However, this study failed to find evidence that perceived stress moderated the relationship between phantom notifications and source monitoring, contrary to what was hypothesized. It may be that the measure of perceived stress used did not operationalize stress in a manner that could capture a state of hypervigilance due to moderate stress. One explanation for this failure may be due to differences regarding types of stress. For instance, previous studies confound the level of stress with the type of stress: researchers used a cold pressor task (Smeets et al., 2008) to induce moderate stress, whereas other studies used traumatic events in an individual's life as a measure of high stress (Strange & Takarangi, 2015b). Thus, in one case moderate stress was physical in nature, whereas high stress was measured as stressful life events. However, the current study only explored perceived stress, which is indicative of yet another type of stress. It could be that some types of stress, such as physical stress or stressful life events, have a curvilinear relationship with source monitoring ability. For instance, highly stressful life events, such as awaiting a phone call regarding an ill family member, might negatively affect source monitoring ability by preoccupying thoughts and therefore increasing the chance of phantom notifications. On the other hand, moderately stressful events might make an individual more aware of their surroundings, therefore increasing source monitoring ability and decreasing the chance of phantom notifications. Perhaps this curvilinear relationship with source monitoring ability is not characteristic of other types of stress, such as perceived stress. Although results of the current study did not find any relationship between perceived stress and source monitoring ability, perceived stress was shown to be predictive of phantom notifications in a linear fashion: higher levels of perceived stress were related to higher frequencies of phantom notifications. These findings suggest that further research is needed to investigate differences between stress type and source monitoring ability. Still, regardless of the differences in stress type and the source monitoring relationship, it may be that other factors are more instrumental in the frequency of phantom notifications.

As such, a second model considered perceived stress as a linear moderator between hallucination proneness and phantom notifications. However, contrary to what was expected, perceived stress was not shown to moderate the relationship between hallucination proneness and phantom notifications. This finding suggests that the relationship between hallucination proneness and phantom notifications is not affected by the individual's perceived stress level. It is possible that perceived stress and hallucination proneness differ in their relationships to phantom notifications. In fact, perceived stress itself was shown to be predictive of phantom notifications regardless of the level of hallucination proneness, indicating that perceived stress is more instrumental than hallucination proneness in determining the frequency of phantom notifications.

Subsequently, the third model investigated perceived stress as a main effect in predicting phantom notifications. It was found that perceived stress emerged as a primary predictor of phantom notifications, regardless of either an individual's hallucination proneness or their source monitoring score. Stress has often been linked to problematic phone use (Augner & Hacker, 2012), so it is possible that the combination of problematic phone use and stress together increase the likelihood of experiencing phantom notifications. Perhaps the stress, or anxiety, of waiting for a phone call or needing to be on the phone adds to the sensory overload suggested by the hypothesis-guided search theory, therefore increasing the likelihood of misinterpreting a different external stimulus as a phone notification and increasing the chance for a phantom notifications. The fact that perceived stress did not moderate a relationship with hallucination proneness or source monitoring ability, but did emerge as a predictor itself, suggests that perhaps this connection between problematic phone use and perceived stress is more indicative of phantom notifications than either an individual's hallucination proneness or source monitoring ability. However, it is important to note that although perceived stress might be more indicative of phantom notifications, hallucination proneness still plays an important role.

Hallucination Proneness and Normative Hallucinations

In addition to the connection to both perceived stress and problematic phone use, it was also found that higher levels of hallucination proneness were related to higher frequencies of phantom notifications. Overall, only 17% of participants reported never experiencing any type of phantom notification, meaning that the majority of participants had experienced a phantom notification at least once. Such a small percentage of people who have never experienced phantom notifications suggests that the occurrence of the experience is fairly common, although there is variability in the frequency of phantom notifications among those who do experience them. The variation in hallucination proneness scores and frequencies of phantom notifications provides further evidence for the continuum view of hallucinations. For instance, the present study suggested that as individuals scored higher on the measure of hallucination proneness, they tended to report more frequent hallucinations in the form of phantom notifications. This relationship indicates that the frequency of hallucinations is related to where one falls in terms of hallucination proneness and the hallucination continuum, a view expressed in previous research (Ohayon, 2000). Consequently, results of this nature could be used as support for the normalization of certain types of hallucinations and to decrease stigma associated with them.

Summary

In summary, results from the present study indicated that source monitoring ability is not related to the frequency of phantom notifications, but that problematic phone use, perceived stress, and hallucination proneness are related to phantom notifications. However, problematic phone use appeared to be the most influential predictor in the model. Together, these results suggest that phantom notifications are manifestations of normative hallucinations and that problematic phone use is instrumental in the development of these experiences.

Strengths and Limitations

There were a number of methodological strengths of the present study. First, the unique topic of the study expands on the extant literature and adds to an otherwise rarely researched topic. Given that cell phones have only become widely used in recent history, a limited number of studies have been published, leaving a large number of gaps in understanding how cell phone usage impacts behavior. Second, a priori power analyses were conducted to ensure that the study reached adequate power of .80. The power analysis ensured that a large sample of over 200 participants would decrease the likelihood of a Type II error, or limit the chance of falsely concluding that certain effects do not exist. Therefore, it is probable that any null effects or relationships found in the present study were not missed due to lack of power to find them. Finally, this study utilized an ethnically diverse sample of undergraduate students. Although ethnic differences were not investigated in the present study, the ethnic makeup of the sample used is similar to that of Southern California, suggesting that the results can be generalized to at least the greater Southern California area.

Despite the study's strengths, there were also a number of limitations. One issue was that participants did not perform well on the source monitoring task, suggesting the possibility of methodological issues with the task. The participants in the present study only accurately identified the sources of 63.2% of the words presented, a number which is much lower than the 89% found in the original study (Hashtroudi et al., 1989). Although verbal confirmation that participants understood the task was obtained prior to the acquisition phase, perhaps the participants did not actually understand the instructions, which could lead to inaccurate source memory scores. In future studies, the use of this task could benefit from a longer practice round or more detailed instructions prior to beginning the task, or a different source monitoring task could be utilized altogether. Additionally, the phantom notification scale created for this study consisted of only three items, thus allowing for the increased possibility of error in the measure. Although internal consistency of the measure was considered good (α = .72), self-report measures with few questions are often prone to error due to the subjective nature of the questions. A longer measure might have more accurately portrayed the frequency of phantom notifications. Future studies should include additional questions to improve reliability;

additional work will need to be conducted on the validity of the scale. Lastly, the study also consisted predominately of female participants due to the high percentage of female undergraduate students in the Human Participant Pool. The low percentage of male participants suggests that caution should be taken when generalizing the results to males. Additional studies should be conducted with similar proportions of male and female participants to ensure that the findings are generalizable to both genders or whether gender differences exist.

Future Directions

Although the present study provides additional information about predictors of phantom notifications, a great deal of research is still needed to learn more about the phenomenon. Future studies could explore the possibility of a distinction between state- and trait-specific hallucination proneness. For instance, differences might exist between people who experience phantom notifications all the time and those who experience them only in times of expectations or emergencies, such as when a family member is ill and an individual is awaiting a phone call. It is also possible that if such a distinction exists, different correlates and causes also might exist for phantom notifications in individuals with state- and trait-specific hallucination proneness. Additionally, future studies should also investigate other manifestations of normative hallucinations, such as hearing one's name called or smelling freshly baked cookies when there are none. Further research on normative hallucinations could increase awareness of these experiences, and therefore decrease stigma associated with them, as well as provide further support for the continuum view of hallucinations.

Conclusion

The growing body of evidence suggests that many individuals experience phantom notifications as a form of normative hallucinations. Contrary to the original hypothesis, the ability to determine whether stimuli come from inside or outside of oneself was not related to the frequency of phantom notifications. The present study did show that problematic phone use, perceived stress, and hallucination proneness were all related to the frequency of phantom notifications, though when considered together, only problematic phone use emerged as a significant predictor.

Collectively, the present study provides support for two main points: phantom notifications are evidence of normative hallucinations and problematic phone use likely plays a role in the phenomenon. The high percentage of participants who had experienced at least one phantom notification suggests that phantom notifications are normative experiences. As normative experiences, phantom notifications provide further support for the continuum view of hallucinations, which spans from normative to clinical experiences. Moreover, problematic phone use is likely to result in more phantom notifications. As the cell phone is a somewhat recent technological advance, research should continue to investigate the potential impact of cell phone use on the mental health of their users.

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