Hearing Protection Use and Intertemporal Choice in Industrial Workers

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Intertemporal choices represent scenarios where costs and benefits occur at different times, during which individuals tend to devalue larger, future rewards in favor of immediate rewards of less value. The degree to which future rewards lose their value is reflected by their temporal discount rate. The relationship between temporal discounting and behavior has been evaluated in a variety of healthcare studies, with many sources reporting a significant relationship between temporal discounting and unhealthy behaviors. The role of discounting has not been applied to understanding hearing protection device (HPD) habits of industrial workers who are overexposed to occupational noise. The purpose of this study is to investigate the relationship between discounting and HPD compliance for industrial workers. We also examine whether self-efficacy is related to compliance. This study applies a self-administered survey instrument to assess demographics, protective behavior, self-efficacy, and limited health information. Discount rates are elicited using a tool that presents a series of hypothetical monetary choices as a proxy. A logistic regression model was used to analyze whether there is a predictive relationship between temporal discount rates and HPD compliance. The collective contributions of discounting, self-efficacy, and demographics were concurrently analyzed in the model. We found no evidence of a relationship between discount rates and HPD behavior. Self-efficacy and gender were significant predictors of compliance, which has been reported previously. Our findings also provide support for broadening research inclusion criteria when studying worker populations in HPD studies. This

study provides the basis for future work investigating the relationship between temporal discounting and HPD compliance.

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1.0 Introduction

One advantage of living in a contemporary society is having the ability to shape and improve one's life through healthy decisions. This autonomy provides opportunities to pursue a variety of pleasurable activities and experiences, but it also can contribute to pain, discomfort, and even death if misused. Disparate health outcomes are inevitable because while individuals may make their own choices, they are not free from the consequences. For instance, a person can choose to consume large quantities of high calorie foods, but they cannot control how this action will affect their waist line. Accordingly, it is every individual's prerogative to consider their health choices and to act in a manner that will provide them with their desired outcomes.

The wisdom behind certain health decisions can initially be difficult to discern, particularly when there is significant time delay between a choice and its consequences. When decisions and outcomes occur at different intervals, some individuals show an inclination for instant gratification over something better that comes later (Chapman, 2005). For instance, an individual may choose to eat a conveniently available fast food meal instead of waiting to prepare a healthier and more satisfying meal at home, or choose excessive drinking over moderation. A similar health dilemma exists in industrial settings where workers who are exposed to high levels of noise must decide daily between wearing the required hearing protection devices (HPDs) designed to preserve their hearing, or forgoing this inconvenience in favor of performing their jobs unburdened, and face a high likelihood of hearing loss in the future. This scenario can be problematic for some because the dangers of hazardous noise are not obvious, and the symptoms of exposure are typically delayed. Many individuals fail to comply with HPD standards and often sustain work-related hearing loss as a result (Seixas et al., 2011). Multiple studies have been dedicated to identifying the basis of this behavior to establish effective interventions that promote compliance. Sources have generally observed that factors such as physical discomfort, the work environment, and beliefs and perceptions related to HPDs and noise are influential. However, no research has considered whether a worker's preferences for future rewards are related to their HPD compliance. Considering the gradual effects of noise on hearing and the delayed advantages of protective behavior, this is likely a factor for at least some people. In this study, we examine the relationship between the HPD habits of individuals who work in a hazardous noise environment and the subjective value they assign to their future hearing health.

1.1 Decision Making

Within the context of economic theory, decision making involves choosing between a set of alternatives when faced with scarcity (Bade & Parkin, 2007). Under this paradigm, something is scarce when there is less of it than people would like. Making decisions also requires comparing the costs and benefits of alternative choices. The cost is what must be given up in order to obtain something, while the benefit is the gain or value derived from a choice. Under these same principles, individuals are presumed to be rational decision makers. Rational choice theory assumes that individuals will weigh costs and benefits when choosing between alternatives and always act in a manner, applying logic and values, that provides them with the greatest benefit or satisfaction (Scott, 2000).

Many of life's decisions are seemingly made without consulting logic or one's best interest, which would constitute irrational behavior. For instance, some individuals make purchases on a credit card without considering their budget, while others repeatedly press the snooze button, leaving insufficient time to prepare for the day. In a health-related context, irrational behavior is observed when industrial workers disregard HPD standards. Individuals abandon protective habits despite their subjection to legal requirements and a possession of the adequate knowledge and training regarding the high probability of acquiring hearing loss without this safeguard (Hong, Lusk, & Ronis, 2005). This is an unfortunate scenario for the non-compliant individual, as the immediate decision to neglect hearing will most certainly have a delayed, but negative effect on long-term hearing health. In an occupational setting, it may be that workers frequently neglect safety due to irrational motivations, such as impulsivity or impatience, as opposed to logic or reason. Such behavior may reflect a preference for immediate gratification over long-term benefits.

1.2 Intertemporal Choice

An intertemporal choice reflects decisions that involve tradeoffs between costs and benefits occurring at different times. Under this philosophy, if given a choice some people would show a preference for smaller, immediate rewards over larger rewards available after a delay (Green, Fristoe, & Myerson, 1994). Normally, when one chooses to delay receiving a reward, it is due to a reasonable likelihood of receiving something better in return for waiting (Lawless, Drichoutis,

& Nayga, 2013). Every day individuals are faced with decisions that require making trade-offs between short and long-term consequences. The decision to wear HPDs in a work setting represents such a scenario, as workers must choose between the immediate benefits of non-use, such as comfort and working unencumbered, and the delayed reward of unimpaired hearing that accompanies daily compliance.

When someone chooses an immediate benefit at the cost of foregoing a larger delayed benefit, this is known as temporal discounting (Hardisty, Fox-Glassman, Krantz, & Weber, 2011). *Discounting* reflects a reduction of the present value of a future reward as the delay to receipt increases (Kirby, Petry, & Bickel, 1999). Therefore, as the receipt of the future reward becomes more distant, the present value of that reward will decrease and will become less likely to be chosen among more immediate alternatives. A real-world example would be if someone offered the choice between receiving $10 today or $20 tomorrow; many people would prefer to wait a day for the $20 because the value of the additional sum is greater than the delay. Conversely, if offered a choice between $10 today or $20 in one year, some would take the $10 because for some people the value of the additional $10 quickly diminishes when the time delay gap increases, even though the actual value would remain constant.

The degree to which present values are diminished with increased delays is depicted by an individual's discount rate. This measure is often used in research to examine behavior and tends to vary broadly between people, with higher discount rates being associated with a lower present value of larger future rewards (Kirby, 1997). That is, a high discounter will typically prefer smaller, immediate rewards over larger rewards available in the future. Discount rates can also vary considerably across research experiments, even when comparing results from the same domain (Frederick, Loewenstein, & O'donoghue, 2002). However, these differences have been attributed more to elicitation methods and techniques rather than instability of the construct (Hardisty, Thompson, Krantz, & Weber, 2013). For example, presenting subjects monetary choices in an experiment often yields higher overall discount rates compared to a matching method (Odum, 2011). Other procedural differences that tend to influence variability include presenting rewards as losses versus gains, the size of the rewards, short versus long delays of receipt, and ordering effects of large versus smaller rewards (Attema, 2012). While elicitation differences often prevent *actual* discount rates from generalizing across studies, there is considerable evidence to suggest that the *relative rate* measured within the context of a study is a reliable comparison for assessing how rapidly a delayed reward loses value for individuals (Barlow, Reeves, McKee, Galea, & Stuckler, 2016; Lawless et al., 2013; Story, Vlaev, Seymour, Darzi, & Dolan, 2014). In addition, the literature suggests that discount rates are a fairly stable measure when testing circumstances are replicated, even for time periods of more than 1 year (Kirby, 2009). Notwithstanding the variability associated with elicitation techniques, discount rates remain as a reliable predictor of real-world health behaviors (Hardisty et al., 2013).

Discounting has traditionally been described using an exponential function, which assumes that subjective reward values decrease parallel to increased delays (Oliveira-Castro & Marques, 2017). Following this model, an individual choosing between two rewards would always select the option with the larger absolute value despite its subjective decrease, even when delayed. Most recent work has recognized that a hyperbolic discount function is more descriptive of actual behavior (Attema, 2012). This model predicts that the subjective value of competing rewards diminishes independently and that a larger delayed reward will eventually decline to the extent that the immediate but smaller reward will be favored, signifying a preference reversal. A hyperbolic discount function graph is displayed in Figure 1, which portrays two bars representing competing rewards of differing value (i.e., one large and the other smaller). The two curves extend away from the rewards to illustrate the subjective changes in value as a function of the delays until they are received. This function demonstrates that an individual faced with a choice between two future rewards might make different decisions depending on *when* they experience the outcome.

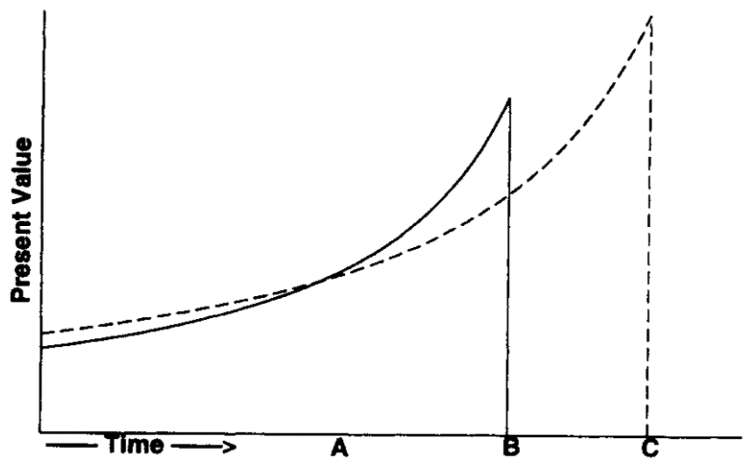

Figure 1. A hyperbolic discount function depicting the perceived values of two delayed rewards as a function of delay. Points B, and C indicate the point of receipt of a smaller, sooner reward and a larger, later reward. Point A represents the preference reversal from the larger to the smaller reward as the delay increases. Reprinted with permission from Kirby et al., (1999).

As unhealthy behavior frequently has a delayed effect on health, many researchers have hypothesized that an individual's tendency to make unhealthy choices is related to their temporal discount rate (Bickel, Odum, & Madden, 1999). Multiple studies have reported positive relationships between discounting and various health behaviors. Strong associations have been observed for activities with addictive components such as smoking (Baker, Johnson, & Bickel, 2003) and drug use (Kirby et al., 1999), as well as those related to physical appetites like sexual behavior (Jarmolowicz, Lemley, Asmussen, & Reed, 2015) and unhealthy eating leading to obesity (Weller, Cook III, Avsar, & Cox, 2008). While statistical significance for preventative health behaviors has been less common, various sources have reported an association with discount rates (Axon, Bradford, & Egan, 2009; Bradford, 2010; Chapman & Coups, 1999; Daugherty & Brase, 2010; Van Der Pol, Hennessy, & Manns, 2017). Demographic differences such as gender, age, income, or education level have generally not been observed as reliable predictors (Bradford, 2010; Johnson, Johnson, Herrmann, & Sweeney, 2015; Kirby et al., 1999; Teuscher & Mitchell, 2011). Interestingly, no literature has examined the potential relationships between discount rates and HPD use. This exclusion is significant because of the delayed consequences derived from hearing protective behavior that is common to other health behaviors related to high discounting, which tends to increase the likelihood of non-compliance (Lawless et al., 2013). This separation between behavior and outcomes is likely to influence some workers to neglect protective standards in favor of the more immediate benefits of non-compliance, which may include improved physical comfort, communication, and perceived spatial awareness (Morata et al., 2001; Patel et al., 2001). The primary motivation of this work is to investigate the role of intertemporal choice on HPD compliance for an industrial worker population by quantifying the relationship between individual temporal discount rates and protective behavior. Secondarily, we aim to concurrently explore correlations between self-efficacy, a known predictor of compliance, and discounting related to HPDs.

Given the delayed consequences of HPD non-compliance and the hidden dangers of occupational noise, we anticipate that less compliant workers will have higher discount rates. Additionally, we expect to observe a significant association between self-efficacy and high discount rates related to compliance. Further understanding of these relationships will contribute significantly to existing behavioral theory related to HPD compliance and provide the basis for novel approaches intended to enhance protective behavior. This work also will contribute to current literature citing discount rates as reliable predictors for other preventative health behaviors.

2.0 Literature Review

Occupational noise exposure is one of the most pervasive health hazards faced by today's workforce (Nelson, Nelson, Concha-Barrientos, & Fingerhut, 2005). There are an estimated 22 million workers exposed to harmful levels of noise at work each year in the US (Tak, Davis, & Calvert, 2009). Consequently, occupational noise has contributed to the acquisition of work related hearing loss for approximately 11 percent of all workers (Masterson, Themann, Luckhaupt, Li, & Calvert, 2016), and continues to impose a significant financial liability to state and federal agencies (Veteran's Affairs, 2017; OSHA, 2017). Like many health conditions, noise induced hearing loss (NIHL) is largely avoidable if individuals heed the counsel of health professionals and adhere to the standards designed to protect them.

From a layperson's view, the prevention of NIHL might seem to be an uncomplicated matter. Because the primary agent of this ailment is noise, simply separating workers from the sound source or dampening the noise to a more temperate loudness level should serve as an effective and practical deterrent. These types of measures are known as administrative and engineering controls, respectively. However, eliminating all sources of noise is neither practical nor desirable in many cases due to occupational requirements. Considering this limitation, federal and state agencies have taken a deliberate approach to address this public health hazard by regulating workplace noise exposure and requiring employers to provide hearing conservation programs (HCPs) for workers whose exposure exceeds a prescribed maximum permissible exposure limit (PEL) (OSHA, 2008). An HCP is an intervention that subjects workers to preventative health measures designed to diminish the harmful effects of noise (Hutchison, 2014). Some of the more prominent program elements include requirements such as engineering and administrative controls, education and training on HCP standards, and regulating the use of HPDs. The most desirable and effective option for preventing hearing loss is achieved through engineering controls, which effectively reduces the intensity of the sound source and diminishes the hazard to workers (Ellenbecker, 1996). Because this alternative is often unrealistic, employers commonly rely on HPDs as the primary safeguard against noise. HPDs can serve as an adequate deterrent to hazardous noise in most environments, but the success of this approach is highly reliant on individuals using HPDs at appropriate intervals. Unfortunately, multiple reports indicate that HPDs are commonly neglected in work settings (Edelson et al., 2009; Lusk, Ronis, & Baer, 1995). Due to this lapse, and because of the significant role that HPD adherence plays in the overall success of HCPs, identifying factors that influence this behavior should be a priority.

2.1 The Role of HPD Compliance

Workers enrolled in an HCP are supplied with an array of HPD styles from which to choose based on individual comfort, their work environment, and other personal preferences. There is both theoretical and practical evidence to support the utility of properly fit HPDs for reducing noise exposure below prescribed levels for most conditions, regardless of the style of the device, provided they are worn properly and possess the appropriate Noise Reduction Rating (NRR) (Royster, Royster, Driscoll, & Layne, 2003). Unfortunately, a variety of sources have observed alarmingly low HPD compliance from workers in various industries, with some studies reporting usage rates of less than 50 percent (Edelson et al., 2009; Lusk, Ronis, & Baer, 1995; Reddy, Welch, Thorne, & Ameratunga, 2012). This lapse leaves many individuals subject to the consequences of non-compliance, which is primarily a high likelihood of hearing loss (Prince, Stayner, Smith, & Gilbert, 1997).

Occupational hearing loss is typically the result of repeated exposures to hazardous noise over many years (Rabinowitz, 2000). However, because susceptibility to noise related hearing loss is highly variable due to genetics and other biological factors, no precise relationship can be inferred between exposure and its effect on hearing (Wilson & McArdle, 2013), although the damaging effects of hazardous noise on human hearing are indisputable. Hearing conservation standards were established on the premise that the risk of sustaining noise related hearing loss is largely a function of the *loudness* of a noise source relative to the *duration* of the exposure (OSHA, 2008). Both the loudness and duration determine the potential for damage to the hearing organ of the cochlea, therefore reducing one or both variables would decrease the risk of sustaining hearing loss. Wearing HPDs can diminish the intensity of noise to the user, though the degree of protection received is largely dependent on the consistency of use. Studies examining the effects of HPD adherence have observed that shortened wear time can have significant effects on the severity and recovery time of auditory fatigue, which is a precursor to permanent hearing loss (Arezes & Miguel, 2002; Irle, Rosenthal, & Strasser, 1999). Additionally, there is direct evidence connecting better compliance to HPD standards with lower rates of occupational hearing loss (Davies, Marion, & Teschke, 2008; Groenewold, Masterson, Themann, & Davis, 2014; Verbeek, Kateman, Morata, Dreschler, & Mischke, 2012). Effectively, hearing health outcomes occur as a function of protective behavior.

Given the structure of HCPs, it is troubling that so many workers do not comply with HPD standards. While programs may vary in their general approach, frequent education on *when* to use HPDs and the health implications of non-compliance is fundamental to any program (Suter, 2002), and serves as an essential advantage in guiding workers towards good hearing health practices. Other common elements include explicit instruction on relevant topics, such as the anatomy and physiology of the auditory system, the impact of hazardous noise on hearing acuity, how to properly use HPDs, and other relevant subjects. Workers also receive constant visual cues in routinely loud spaces that prompt them to utilize protective devices, such as clearly marked warning signs alerting them to the presence of hazardous noise, and strategically placed supplies of HPDs (Daniell et al., 2002). The occupational requirements associated with HCP regulations also can be motivation to follow HPD standards, as workers may face disciplinary actions or even fines for their negligence. Considering this model of care, HCP interventions and the professionals who administer them seem to be uniquely positioned for success. Yet, the magnitude of workers who neglect to wear HPDs suggests that education and regulation alone are not sufficient drivers of healthy behavior related to hearing loss prevention. HPD compliance appears to be a more complicated issue with multiple contributing variables.

2.2 Predictors of HPD Use

One of the prevailing challenges that healthcare providers face is persuading patients to make healthy decisions. Individuals often neglect sound medical guidance in favor of unhealthy alternatives to the detriment of themselves and society. Perhaps most discouraging is the awareness that professional competence plays only a supporting role in producing desirable health outcomes, whereas individuals are ultimately responsible. Considering this reality, discerning how to compel individuals to make healthy choices is a critical component of modern medicine. Accordingly, it is essential that providers possess a firm understanding of the variables that influence, and even predict individual decisions in the pursuit of interventions that will incentivize healthy behavior.

Many organizations rely heavily on worker's adherence to HPD standards to achieve healthy outcomes. While this arrangement is convenient for employers, workers are regrettably left to bear the primary burden of hearing conservation. This approach is not ideal given the potential sources of disruption, particularly those related to an individual's likely primary interest of meeting job demands as conveniently as possible. Because of the heavy reliance on employee initiative, efforts to improve HCP outcomes should center around those factors that impact worker behavior. A logical first step in this effort is to conduct an exhaustive review of the literature addressing this issue, considering both practical and theoretical elements, to determine which variables are most influential. This exercise will provide clarity regarding a worker's disposition towards wearing HPDs, highlight the most useful aspects of HCP structure, and support resource prioritization. Additionally, an understanding of the theoretical properties of behavior may facilitate new and innovative interventions that may not have been considered previously.

The notion that disparities within populations contribute to variable behavior is not a novel concept. Individual circumstances, belief systems, and diverse surroundings will invariably have an influence on one's decision making. However, there are some qualities related *specifically* to wearing HPDs that tend to influence compliance. For instance, some individuals might forgo protection due to a perceived disruption to communication while using them (Reddy et al., 2012), whereas others may experience physical discomfort from wearing the devices (Morata et al., 2001). Disparities in the perceived loudness of noise sources (Sbihi, Teschke, Macnab, & Davies, 2010) and social influences from colleagues also will affect worker's choices (Cheung, 2004). As previously indicated, there may be other undiscovered theoretical contributions that would provide understanding. A wide range of studies have considered why workers neglect HPDs, resulting in the identification of several variables that explain this behavior. These findings are broadly ranged, but they settle into larger themes that naturally diverge into three major categories, (1) physical comfort, (2) beliefs and perceptions, and (3) environmental factors. These divisions represent what is currently known about the motivations behind individuals choosing to wear HPDs in a work setting. The purpose of this section is to systematically summarize these variables, while also highlighting their contribution towards explaining worker behavior. Ultimately, the limitations and omissions from each of the domains identified in the literature will be considered and a rationale for further research in this area using a novel approach will be provided. Only studies that address HPD use for workers exposed to hazardous noise at work are included. Various studies have addressed protective behavior related to hearing in other populations and contexts, such as adolescents at rock concerts, musicians, and others. However, we considered these groups sufficiently different from individuals who are exposed to noise while performing their occupation. Differences include their assumed motivations for wearing HPDs, accountability to an employer and state and federal regulations, consistent guidance towards HCP compliance, and the chronic nature of the noise exposure.

2.3 Physical Comfort

Some occupations are characterized by unique hazards that present a realistic possibility of sustaining physical harm. The dangers posed by such threats are often overt and associated with obvious physical consequences if safety procedures are not followed. For instance, a welder is likely to understand that abstaining from eye protection carries a high likelihood of pain and injury from hot pieces of metal spraying near his face. Unfortunately, the possibility of acquiring hearing loss from working in a hazardous noise environment is not as pronounced. Consequently, one of the obstacles that noise exposed workers face in complying with safety standards is the perceived distance between non-compliance and sustaining physical harm. Because the impairment caused by hazardous noise is frequently imperceptible, does not cause physical discomfort, and is usually delayed, workers may be inattentive to the progressive nature of their injury and may be less inclined to wear protection (Shohet & Bent, 1998). The absence of a perceived threat of hearing loss is also likely to lead some to carry an indifferent attitude towards working around noise levels that they perceive as comfortably loud, but which can still be harmful to the auditory system (Rabinowitz, 2000).

While some individuals are unconcerned by noise, there are cases where working in a noisy environment can cause physical distress or otherwise become bothersome (Melamed & Bruhis, 1996). In other instances, noise levels may become exceptionally loud to the point where workers feel physical pain. Under these circumstances, the desire to improve physical comfort, or escape discomfort, should provide sufficient motivation to comply with safety standards. Conversely, some individuals will avoid wearing HPDs for extended periods due to physical irritation or pain caused by the devices themselves. These examples illustrate that sometimes an individual's decision to engage in safe behavior is not necessarily a thoughtful process, but may be reflexive and based on self-preservation, irrespective of their disposition towards their health and safety.

2.3.1 Noise Annoyance

One of the more prominent non-auditory symptoms of occupational noise exposure is stress. Noise related stress at work has been linked to several adverse health effects, including decreased job satisfaction, increased errors, and loss of concentration (Leather, Beale, & Sullivan, 2003). The most commonly cited perceptual correlate to noise-induced stress is generally characterized by workers as noise annoyance (Reddy et al., 2012). An elevated perception of noise annoyance has been cited as an important determinant for deciding to comply with HPDs, even when loudness levels were well below PELs, which suggests considerable variability in noise tolerance among workers (Melamed, Luz, & Green, 1992). In certain occupational settings, prolonged overexposure to noise can be particularly vexing given that the irritant is constant and often inescapable. Multiple studies have observed an association between noise annoyance and HPD use, citing that workers who reported greater levels of annoyance tended to use HPDs at work at higher rates compared to those who were less annoyed by noise (Melamed et al., 1992; Melamed, Rabinowitz, & Green, 1994). These findings suggest that noise annoyance is a catalyst for some workers to comply with HPDs, serving as a means to escape noise-related stress.

2.3.2 Loudness Levels

While all noise sources are not sufficiently bothersome to induce workers to wear HPDs, eventually sound levels will exceed the threshold of comfort for most individuals. When noise levels surpass the limits of physical comfort, individuals are more likely to comply with HPD standards regardless of their disposition towards safety compliance. In most cases, studies seeking to explain HPD compliance have observed that workers who were exposed to higher noise levels tended to wear HPDs more frequently than those who worked in lesser amounts of noise (Melamed et al., 1994; Sbihi et al., 2010). While this finding is rather predictable, the information provides a valuable piece to the larger picture of what influences HPD use. Self-monitoring of noise exposure levels is not an especially useful cue for protective behavior, as most individuals are not adept at identifying when noise levels have surpassed recommended PELs (Rabinowitz, 2000). This method may be even less reliable when considering the variability in individual hearing sensitivity and discomfort thresholds (Lusk, Kerr, & Kauffman, 1998).

2.3.3 Physical Fit of HPDs

There are some individuals whose intentions to comply with hearing safety standards are frustrated by significant discomfort experienced while wearing HPDs. Worker complaints related to comfort issues have ranged from actual physical pain, such as headaches and tightness in the ear canal, to itchiness and sweating (Hsu, Huang, Yo, Chen, & Lien, 2004; Reddy et al., 2012). Discomfort from HPDs may result from several factors, such as the mass of the device in the ear, the shape of earmuff cups, the properties of the materials in contact with the skin, and other causes (Williams, 2009). Regardless of the specific complaints or cause of discomfort, it is adequate to acknowledge this as a significant hindrance for some individuals adopting HPDs at work. Fortunately, this barrier can be overcome in most cases by simply introducing an adequate selection of HPDs with multiple size and material options. The Occupational Safety and Health Administration (OSHA) federal regulation addressing HCP standards specifies that employers must provide a *variety* of HPD options for workers enrolled in the program (OSHA, 2008). Although, consistent with the regulation's purpose of providing a minimum standard, the term *variety* can be interpreted to fit the employer's objectives. This means that some workers will likely need to self-advocate to receive adequate protective equipment. Because not all individuals in this predicament will promote their needs, there will be some who either neglect to wear HPDs or continue wearing a poorly fit device. In marginal cases where workers have an abnormal sensitivity to HPD materials or a skin disorder, custom HPDs with hypoallergenic properties are an option, as well as circumaural muffs that have limited contact with the ear.

One notable caveat pertaining to HPD compliance is that while there are undoubtedly cases where workers struggle to tolerate HPDs in their ears, it is also possible that much of the reported discomfort is based on comfort relative to not wearing HPDs. In other words, if given the option most individuals would likely prefer the sensation of not wearing HPDs over wearing them. This assumption calls into question the validity of at least some cases of reported discomfort.

2.3.4 Limitations

Factors related to physical comfort emphasize that some individuals will engage in using HPDs to escape the uncomfortable effects of hazardous noise, while others will abstain due to discomfort caused by the devices. This perspective is limited in its scope and leaves other aspects of compliance unaddressed. For instance, there is little evidence to support that large numbers of workers report high degrees of noise annoyance, as the studies examining this subject found that those who were highly annoyed by noise were generally in the minority (Melamed et al., 1992; Melamed et al., 1994). Similarly, most work environments do not produce noise levels high enough to produce loudness discomfort (Sbihi et al., 2010), nor is there an indication that a significant amount of workers reject HPDs due to fit or sensitivity issues (Morata et al., 2001). These findings indicate that while aspects of physical comfort influence worker HPD use, they likely play a limited role in producing high rates of non-compliance.

2.4 Beliefs and Perceptions

Most would agree that the way individuals think about their health has a strong influence on how well they take care of their bodies. It also can be reasoned that the likelihood that an individual will make healthy decisions is often a function of the value they assign to their health. This means that if individuals think certain health practices will improve their physical well-being, assuming good health is their goal, they are more likely to engage in those behaviors. Because human behavior is so influential in many of the leading causes of disease around the world, scientists have developed theories and models to study health behavior in a systematic way. Others have simply speculated that particular beliefs and perceptions likely play a significant role in how health decisions are made. Numerous studies have tested these hypotheses by examining how individual beliefs and perceptions influence health behaviors, including many that have considered HPD compliance in individuals who work in hazardous noise. The motivations behind these studies range from assessing the effectiveness of conventional training and education-based interventions designed to encourage compliance, to the establishment of a causal model to identify factors that are predictive of HPD use with the intention of developing new interventions (Lusk & Kelemen, 1993).

Much of the work investigating the effects of beliefs and perceptions on worker's behavior utilized theory from the Health Belief Model (HBM) and Health Promotion Model (HPM). Many of these studies sought to operationalize elements from the models to develop psychometric instruments intended to measure the constructs specific to the model framework. Responses to various survey items were analyzed and then used to identify which constructs contributed significantly to HPD use. Findings from these studies facilitated the identification of a variety of model components that determine HPD compliance. Other models, such as the Transtheoretical

Model of Change (TTM) and the Extended Parallel Model (EPM), were applied in a similar manner. Finally, several studies considered the role of perceived risk pertaining to the acquisition of noise related hearing loss. However, it should be noted that perceived risk of hearing loss is common to multiple models, which emphasizes the considerable overlap between their frameworks. Despite this duplication, each model discussed in this review has distinct characteristics which warrant separate treatment. Table 1 summarizes the models and approaches considered in this section, including key concepts.

Table 1. Models and approaches used to examine HPD behavior from Beliefs and Perceptions domain

Model/Approach	**Key Constructs Addressed**
Health Belief Model	Perceived susceptibility, perceived severity, perceived benefits, perceived barriers, self-efficacy, cues to action
Health Promotion Model	Self-efficacy, perceived benefits, perceived barriers, activity-related effects, modifying factors, interpersonal influences
Protection Motivation Theory	Perceived self-efficacy, perceived response efficacy, perceived severity, perceived vulnerability
Transtheoretical Model of Behavior Change	Stages of change: pre-contemplation, contemplation, preparation, action, maintenance
Extended Parallel Process Model	Perceived susceptibility, perceived severity, self-efficacy, response-efficacy
Theory of Planned Behavior	Attitudes, subjective norms, perceived behavioral control
Risk Perception	Perceived risk

2.4.1 Health Belief Model

One of the most widely applied theories to evaluate health behavior is the Health Belief Model (HBM), a framework developed to explain why preventative health standards are neglected (Orji, Vassileva, & Mandryk, 2012). The primary assumption of this model is that an individual's likelihood of engaging in a given health behavior is determined by their perceptions pertaining to five variables: perceived susceptibility to an ailment (*perceived susceptibility*); perceived severity of the consequences of the health condition (*perceived severity*); perceived benefit of taking action (*perceived benefits);* perceived barriers to carrying out the health behavior *(perceived barriers);* and the perception that one can carry out the health behavior *(self-efficacy).* This framework also concedes that modifying variables, such as race and gender, and the presence of cues that prompt action, or cues to action, contribute to the behavior as well. The structure of this model has been utilized in many studies for understanding factors that contribute to various health behaviors (Janz & Becker, 1984). Unfortunately, it has only been applied sparingly in the evaluation of worker's HPD use.

The most comprehensive worker-related HPD study to apply this model was conducted by Hong and Ronis (2013) who included all the HBM constructs to examine their association with firefighter's protective behavior while working in noise. The researchers administered online surveys to subjects across 3 different US states to elicit responses pertaining to the perceptual and modifying factors from the model. After applying the data to a regression model, they observed that perceived barriers and perceived susceptibility were significant predictors of HPD behavior. They also noted that social influences and organizational support were important modifying factors. Unfortunately, the scope of the study only considered fireman, which may preclude these findings from readily generalizing to other populations that experience a more constant dose of noise compared to this group.

The only other relevant work to examine predictors of HPD use in workers was focused primarily on the perceived barriers portion of the HBM (Patel et al., 2001). Researchers conducted a largely exploratory study that asked workers to discuss the specific types of barriers that they perceived as deterrents to HPD use. They led multiple focus groups with randomly selected coal miners from 2 separate work environments to gather and synthesize responses to identify prominent themes. The miners broadly indicated that barriers related to their environment, as well as individual barriers related to their own perceptions, were the biggest obstacles for complying with HPDs. Some specific obstacles included a perceived inability to communicate on the job while wearing HPDs, a lack of support from peers and supervisors, and general discomfort. While this study was largely exploratory and limited in scientific rigor, one noteworthy residual finding was that the presence of perceived barriers to HPD use seemed to have a hierarchal influence over the other constructs. This was expressed by several subjects revealing their tendency to avoid using HPDs, irrespective of their other perceptions, unless they felt that barriers were first removed. Other investigations have considered the influence of variable ordering and interactions of HBM constructs, many of which have observed both hierarchal and moderating effects of some HBM constructs, which lends credibility to the findings described in this study (Jones et al., 2015).

Although evidence to support the HBM as a framework for considering HPD use is sparse, the constructs from this model appear well-suited for capturing the relevant elements of this health behavior. Because worker's vulnerability to noise-related hearing loss is often intangible, workers should possess perceptions that are conducive to protective behavior. Additionally, the perceived self-efficacy component from the model has been noted by other studies as a prominent factor for wearing HPDs at appropriate intervals (Melamed, Rabinowitz, Feiner, Weisberg, & Ribak, 1996), a point that will be discussed in later sections. Finally, many of the common HCP components may serve as cues to action for HPD use, such as available HPDs and posted noise hazard signage. Despite the expected suitability of this model, there are 2 important limitations for its use in this context. The model does not account for behavior over a time continuum or acknowledge that beliefs and perceptions may change over time depending on new experiences. The model does not account for decisions made from emotional or impulsive instincts, or other motivations that neglect thought or reason.

2.4.2 Health Promotion Model

The Health Promotion Model (HPM) was conceived by Nola Pender in an effort to provide an inclusive framework for explaining health behavior (Lusk & Kelemen, 1993). The model was primarily derived from conventional social-cognitive theory and was intended as an improvement over the HBM with the assumption that additional variables were needed to provide a comprehensive view of health-related decision making. Specifically, it was asserted that while individuals often engage in health behavior to avoid illness or injury, largely a defensive effort, they also desire to actively regulate their own well-being through the engagement of health promoting activities (Lusk, Ronis, Kerr, & Atwood, 1994). Comparable to the HBM, Pender's framework concedes that modifying factors such as demographics and situational effects can guide behavior, but also recognizes the role of interpersonal influences, such as organizational and peer support (Ronis, Hong, & Lusk, 2006) . The model also utilizes some of the elements from the HBM such as *perceived self-efficacy*, *perceived benefits*, and *perceived barriers*, but enlarges the scope by incorporating perceived *activity-related affects*, which represent subjective feelings or emotions related to a specific behavior. Like the HBM, the structure of the HPM has been utilized to consider factors that explain worker's compliance to HPD standards, although much more extensively.

When the HPM was initially conceived as a framework for understanding HPD compliance, it was intended to function as a predictive model, contrary to its more common use as merely a guideline for the study of health behavior (Lusk, Ronis, & Kerr, 1995). Since then, several groups have analyzed HPD behavior through the lens of the HPM components, using both novel and established instruments to depict and measure aspects of the model constructs. Lusk and Kelemen (1993) were the first to carry out this work by examining the relationship between the HPM elements and HPD use in metal shop workers exposed to occupational noise. Subjects were asked to indicate the percentage of time that protection was required to be worn at work, relative to the percentage of time that they complied. Survey instruments were then administered to measure aspects of the HPM constructs, with the intention of identifying the most important predictors of HPD use and their relative contribution. Various modifying factors and perceptions were found to predict HPD behavior, similar to the HBM studies described previously. Subsequent studies have been carried out by Lusk and colleagues, as well as other groups, in an effort to authenticate results and to further establish the HPM as a predictive model (Edelson et al., 2009; Kim, Jeong, & Hong, 2010; Lusk et al., 1994). The most prominent studies and their findings are highlighted in Table 2. Some recurring trends from this work have shown that *perceived self-efficacy*, *perceived barriers*, and *perceived benefit*, were predictive of HPD use (Kerr, Lusk, & Ronis, 2002; Lusk, Ronis, & Hogan, 1997; Lusk, Ronis, & Kerr, 1995), as well as modifying factors, such as social support and accessibility of HPDs (Kim et al., 2010; McCullagh, Ronis, & Lusk, 2010). The literature also provides insight on workers from a variety of noise exposed occupations, including construction (Ronis et al., 2006), farming (McCullagh, Lusk, & Ronis, 2002), and manufacturing (Lusk et al., 1994). A few studies examined contributing factors related to HPD behavior in minority groups, which found similar trends (Hong et al., 2005; Kerr et al., 2002; Raymond, Hong, Lusk, & Ronis, 2006), though overall the models were less predictive for these populations. The variety and abundance of research on this topic and the repeated results provide significant credibility for the HPM as a predictive framework for assessing HPD compliance. However, like the HBM this model does not account for fluctuating beliefs and perceptions over time related to HPDs, nor spontaneous decisions.

Table 2. Predictors of HPD use identified with the Health Promotion Model

	Health Promotion Model Perceptions			
Study	**Self-efficacy**	**Benefits**	**Barriers**	**Activity-related effects**
Lusk & Kelemen (1993)		√		
Lusk et al. (1994)	√	√	√	
Lusk, Ronis, & Kerr (1995)	√	√	√	√
Lusk, Ronis, & Baer (1997)	√		√	
Lusk, Ronis, & Hogan (1997)	√	√	√	√
McCullagh, Lusk, & Ronis (2002)			√	√
Kerr, Lusk, & Ronis (2002)	√	√	√	
Hong, Lusk, & Ronis (2005)		√	√	
Raymond et al. (2006)		√		
Edelson et al. (2009)		√	√	
Kim, Jeong, & Hong (2010)		√		
McCullagh, Ronis, & Lusk (2010)			√	

2.4.3 Other Models

An assortment of other recognized behavioral models have been employed to examine their utility for understanding HPD use. Although, these studies are much less plentiful and less rigorously considered than the previously described work, many of them offer unique contributions to understanding this health behavior. For instance, one group utilized elements of the Protection Motivation Theory (PMT) as a framework for investigating compliance in a manufacturing setting. The central assumption of this theory is that individuals will participate in health behavior as a direct function of their motivation to protect themselves (Melamed et al., 1996). This model has several factors in common with the HBM and HPM but differs in its structure and assertion that health-related behaviors are performed as a function of two distinct cognitive processes, which are the coping appraisal and threat appraisal. These domains signify the consequences that one can expect from engaging or not engaging in a specific behavior. Under the coping appraisal domain are the constructs of *perceived self-efficacy* and *response effectiveness*, which reflects an individual's perceived benefit of acting. The threat appraisal domain includes *perceived severity* and *perceived vulnerability*. Comparable to the previously reviewed models, perceived susceptibility to hearing loss and self-efficacy were observed to be significant predictors of HPD compliance. The studies performed with this framework, while sparse, lend support for conducting future work of its kind, and provide additional credibility for the constructs from the aforementioned models as predictors of HPD use. The organization of this model presents a realistic portrayal of a worker's perception of potential occupational hearing loss, as one must consider how to deal with this health hazard, relative to their perceived risk of sustaining hearing loss. However, this framework may be inadequate for those who do not feel threatened by hearing loss, which is likely given the absence of a visible threat.

The Transtheoretical Model of Behavior Change (TTM) alleges that individuals differ in their capacity to adopt healthy behaviors relative to their current stage of readiness to adopt such behavior (Kalampakorn, 2000). Each stage is characterized by the likelihood of engaging in a specific behavior and follows a hierarchal progression as follows: *pre-contemplation* (not considering behavior), *contemplation* (considering but not ready to perform behavior), *preparation* (preparing to adopt behavior), *action* (actively performing behavior), and *maintenance* (maintaining the behavior). An individual may *relapse* to a previous stage at any point. The two studies that used the TTM to understand HPD compliance assessed the ability of this framework to accurately characterize reported behavior, including whether the action stage was an appropriate indicator of HPD behavior (Kalampakorn, 2000; Raymond III & Lusk, 2006). They also wanted to know at what stage most individuals were in the model. Based on reported HPD behavior at different time intervals, the researchers inferred that the structure of the TTM was a useful framework in determining HPD use, and noted that while most workers had adopted some degree of the behavior, most were not at the desired action stage. Additional work is needed to establish the utility of this framework as a predictive tool, though it presently seems to be useful for identifying a worker's likelihood of adopting HPD use, which may allow providers to better prioritize intervention strategies. This model provides a unique perspective for the consideration of HPD behavior, particularly due to its inclusion of a temporal dimension signified by the distinct stages of change. This view of behavior adoption as an ongoing process also recognizes that the factors relevant to HPD compliance likely have hierarchal significance, and that engaging in a behavior may be reliant on the interaction of variables for some individuals, rather than singular elements. Though, one major downside of the TTM is the arbitrary delineation between stages, which limits the generalizability of study results. This framework also does not consider the role of mediating factors, such as social context or environment, which is likely an important issue given the variability of occupational settings. Finally, the model neglects to account for unplanned decisions, which is a limitation shared by other behavioral models.

Another approach used to forecast HPD behavior is the Extended Parallel Process Model (EPPM), which describes how logic and emotions combine to determine behavioral decisions (Popova, 2012). This model asserts that an individual's motivation to perform a behavior is regulated by how threatened they feel, which is characterized as *perceived susceptibility* and *severity*. Whereas, the capacity that one feels they have to reduce or prevent the threat determines the action itself, which is represented by *self-efficacy* and *response-efficacy* (Murray-Johnson et al., 2004). The only study to consider this model for the assessment of HPD use was done by Murray-Johnson et al. (2004), whose largely exploratory work relied on focus groups comprised of Appalachian coal miners to gain understanding of their feelings and perceptions regarding the vulnerability of their profession to occupational hearing loss. The responses were recorded, transcribed, and later analyzed for common themes relevant to the EPPM dimensions. The researchers observed that workers generally had adequate perceived severity of hearing loss, though many did not feel they were particularly susceptible to new hearing loss due to pre-existing cases. In addition, many workers indicated reduced levels of *self* and *response efficacy* as motivation for HPD non-compliance, citing excuses related to lack of convenience, high cost, poor fit, and lack of confidence in the HPDs to protect their hearing. Like other models, the EPPM correctly recognizes the role of perceived threat of hearing loss and HPD self-reliance in hearing loss prevention. This view of behavior also recognizes that HPD use may occur as an instinctive reaction, like responding to a physical threat, rather than a thoughtful practice. Although, in addition to a lack of available research and scientific rigor with this framework, the limited focus of these concepts neglects several influential factors highlighted by other studies, such as the perceived benefit of compliance and social influences.

Finally, the Theory of Planned Behavior (TPB) states that one's intention to perform a specific health behavior is an immediate antecedent to performing that behavior. This model relies on the contributions of several elements that collectively determine an individual's intentions, to include *attitudes* related to the consequences of behavior, the perceived expectations of others known as *subjective norms*, and *perceived behavioral control* which is synonymous with self-efficacy (Ajzen, 1991). One study sought to comprehend worker's intentions to wear HPDs by using the structure of the TPB constructs (Quick et al., 2008). The researchers mailed a series of surveys to miners from various coal mines to measure the model elements, the intentions of the workers to comply with HPDs at work, and their reported use while working in noise. Reported use was assumed to reflect an intention to wear HPDs. The surveys were delivered at two time-intervals and provided information and recommendations for wearing HPDs. The study found that each of the model components were significant predictors of intentions to wear the devices in noise, particularly attitudes related to wearing HPDs, and that intentions to wear HPDs were positively associated with reported use. The TBM appears to be among the more comprehensive models for examining HPD behavior as it covers a wide range of variables known to be influential. Unfortunately, the model has similar drawbacks as some of the others reviewed, which include its lack of consideration that behavior can change over time and the assumption that behavior is the result of a systematic decision-making process. Additional research could vindicate its use for studying HPD behavior.

2.4.4 Risk Perception

It is reasonable to expect that individuals will base health decisions on the likely consequences of their behavior relative to the anticipated benefits (Ferrer & Klein, 2015). In fact, this is a necessary daily exercise for those working in hazardous noise conditions who often must forgo pleasurable activities at work, such as listening to music or engaging in casual conversation with colleagues to preserve their hearing. When faced with this choice, one's actions will typically be based on a subjective calculation of anticipated outcomes rather than a quantitative process (Arezes & Miguel, 2005a). This viewpoint illustrates that an individual's perception of risk is an important precursor to their health behavior. Under this notion, if a person does not feel they are at risk of a negative health consequence they are unlikely to take the necessary action to prevent it.

There is ample literature addressing the role of risk perception on a worker's decision to wear HPDs, although this work has been supplied almost exclusively by one research group. Arezes and Miguel (2005a, 2005b, 2006, & 2008) have conducted multiple studies examining the relationship between an individual's perceived risk of acquiring noise related hearing loss and compliance to HPD standards. Each of these studies utilized a survey instrument designed to capture various aspects of perceived risk of hearing loss to provide a review of the contributing components for HPD compliance. Their analyses found evidence that an individual's perceived level of danger from being exposed to hazardous noise was the most predictive of HPD use (Arezes & Miguel, 2005b). Another significant aspect of risk perception noted by the research group was self-efficacy, which reflected the degree to which subjects felt they could protect themselves from noise. This discovery is not surprising given the role of self-efficacy described in other studies (Lusk et al., 1994).

While the literature provides compelling evidence for perceived risk of hearing loss as a major factor in HPD use, there are some weaknesses in this approach that should be considered. First, some of the research indicated that many subjects were poor judges of their own level of risk. This can be inferred by the questionnaire responses indicating that some individuals identified high-risk noise sources simply as those that made them feel uncomfortable, irrespective of the actual noise levels (Arezes & Miguel, 2005b). This discrepancy possibly contributed to a poor estimation of perceived risk, thus biasing the results and interpretation. In addition, despite the sample being taken from individuals who enrolled in an HCP, many individuals did not view their workplaces as significantly dangerous to warrant using HPDs. These discrepancies indicate that while many of the workers had a firm understanding of the general risk of occupational hearing loss, some were not aware of the risks associated with their own circumstances. This drawback was further highlighted by the low correlations found between the actual degree of risk, or the risk index, and reported HPD use observed in some of the data (Arezes & Miguel, 2008). Examining HPD compliance with this approach has some practical and theoretical issues. Besides the lack of consideration for other known predictive variables, perceived risk may not be relevant to some workers. Additionally, an individual's perceptions are highly variable and often dependent on circumstances that are unlikely to remain constant over time. For example, an individual may be assigned to a new workspace that they perceive to be less loud, or someone may sustain some degree of hearing loss and feel that they are no longer susceptible to further loss. This suggests that perceived risk measures are not sensitive to time and circumstances, thus limiting their utility as an indicator of HPD use. Lastly, this view of behavior assumes a rational thought process, when behavior is often deficient of reason.

2.4.5 Model Homogeneity

It was previously conceded that many of the behavioral models utilized in the literature have multiple common elements. While each of the models from this work has a distinct framework and unique assumptions, there are many overlapping ideas that merit attention and that illustrate the larger approach taken to evaluate predictors of HPD behavior within the Beliefs and Perceptions domain. Considering these similarities, a summary of the points of intersection between construct groups are highlighted in Table 3. The table is organized with the models listed on the left column and the construct group designations listed above. Given the breadth and variety of the HBM structure relative to the others, this framework was used as a standard to compare and organize the other models. Each construct was reviewed in the literature to assess its meaning and assigned to a group designation that most closely resembled its conceptual correlate. Out of the 5 construct groups considered in the table, the *self-efficacy* group was common to all but one of the models, followed by *perceived benefit*. *Perceived susceptibility* and *perceived severity* were found in about half of the models, whereas *perceived barriers* were the least prevalent construct. The considerable overlap between the models provides support for these factors as predictors of HPD behavior. However, this also demonstrates the narrow approach taken by prior studies for the consideration of beliefs and perceptions relevant to HPD use, which lends support for a larger variety of research on this topic.

Table 3. Behavioral models, main construct categories, and points of intersection

	Construct Group Categories and Correlates				
Behavioral Model	**Perceived Susceptibility**	**Perceived Severity**	**Perceived Benefit**	**Perceived Barriers**	**Self-Efficacy**
HBM	Perceived Susceptibility	Perceived Severity	Perceived Benefit	Perceived Barriers	Self-Efficacy
HPM	---	Activity Related Effects	Perceived Benefit	Perceived Barriers	Self-Efficacy
TTM	---	---	---	---	Preparation
EPPM	Perceived Susceptibility	Perceived Severity	Response Efficacy	---	Self-Efficacy
TPB	---	---	Attitudes	---	Perceived Behavioral Control
Risk Perception	Perceived Risk	---	---	---	---

2.4.6 Limitations

There is clearly an abundance of literature addressing beliefs and perceptions related to HPD use. Within this arsenal of research, recurrent themes have been observed related to predictors of HPD behavior, such as perceived self-efficacy, perceived benefits of wearing HPDs, risk perception related to hearing loss, perceived barriers to HPD use, and others. There is nothing particularly incorrect with the described approaches, nor is there likely a perfect model or methodology that would capture all the relevant factors that determine HPD behavior. However, there are a couple of notable limitations relevant to these collective approaches. First, most of the models or concepts from the reviewed literature do not account for worker behavior over a time continuum. This assessment concedes that one's opinions and perceptions are likely to change over time based on experiences, maturity, and other variables, which may be influential on worker's HPD habits. The lone exception is the TTM which recognizes behavior adoption as a process that is *eventually* achieved. However, this model does not account for behavior that may fluctuate based on the perceived relative value of compliance versus non-compliance. Time-inconsistent HPD behavior is an especially relevant issue because *any* exposure to hazardous noise levels, or lapse in HPD compliance, has the potential to contribute to irreversible hearing loss. Although most of the reviewed models are not structured to address this element, several of the cited studies did provide some evidence that HPD use was somewhat dependent on demographics that are sensitive to change over time, such as age, job experience, education levels, and other factors (Arezes & Miguel, 2005a; Edelson et al., 2009; Sbihi et al., 2010). However, these variations do not appear systematic. The other sizeable omission from the literature is the lack of consideration for decisions made without forethought or consideration of consequences. This sort of conduct may be rooted in impulsivity or impatience, so long as it reflects a preference for immediate gratification over long-term benefits. To date, no HPD related work has considered the effect that a preference for immediate satisfaction might have on compliance. Conversely, many studies have examined other health behaviors in this context, such as smoking, risky sexual behavior, and engagement in exercise, and have observed that a propensity for immediate rewards did have bearing on unhealthy conduct (Bradford, 2010; Chesson et al., 2006; Tate, Tsai, Landes, Rettiganti, & Lefler, 2015). Many of these health activities have common elements relative to HPD use, such as their preventive nature, and a lack of immediate consequences. Because individuals who are exposed to hazardous noise at work must choose daily between the immediate comfort of performing their job unencumbered by HPDs, and consistently wearing protection in return for preserved hearing in their advancing years, it is likely that some workers will choose the former. Given the constant attention required to prevent occupational hearing loss, addressing these omissions could provide novel insight into this health issue, assist providers and researchers in better educating workers, and create more meaningful and effective interventions.

2.5 Environmental Factors

The setting in which individuals perform their job can have a significant influence on their inclination for safe behavior (Bockstael, De Bruyne, Vinck, & Botteldooren, 2013). Every work environment has distinct characteristics reflective of its climate or culture. Relative to a work setting, one source described a culture as the set of shared attitudes, values, goals, and practices that characterizes an institution or organization (Merriam-Webster, 2004). In the same context, a climate has been designated as the perceived work atmosphere that is created by the established policies, procedures, and practices of an organization (Brady & Hong, 2006). Thus, it is reasonable to state that a climate is a reflection of an organization's culture. Given these characterizations, one can readily concede the importance of establishing work-related conventions in which HPD compliance is highly valued. While federal regulations require all companies to administer the minimum HCP standards, many of these criteria are vague and open to interpretation. This latitude enables work environments to be molded to fit the values of its members, which may or may not be conducive to sound HPD practices. With respect to encouraging conventional HPD behavior, sources have demonstrated that the attitudes and behavior displayed by management and employees are significant, as well as the guidelines and processes established to encourage safety (Bockstael et al., 2013). Variability in individual noise exposure levels are influential (Costa & Arezes, 2014). Regardless of an individual's predisposition for using HPDs, many sources have illustrated that environmental factors can greatly influence behavior.

2.5.1 Social Support

An organization's safety climate is often expressed through employee behavior. When the larger body of workers adhere to established regulations, it is likely that others will follow suit. Manager or supervisor behavior can be especially influential, either for or against compliance, given their role as leaders and mentors (Cheung, 2004). Setting an example of safety is an essential feature for stimulating adherence to HPD standards, given the many barriers specific to this behavior. Hazardous noise environments often provide unique challenges for workers that can sway them towards non-compliance, such as impaired communication and reduced environmental awareness (Morata et al., 2001; Reddy et al., 2012). This can be an especially challenging dilemma for inexperienced workers who are simultaneously learning novel tasks and becoming familiar with a new environment and colleagues. Multiple studies have assessed the effects that social influences have on HPD use and have generally observed that high levels of perceived social support were correlated with greater compliance (Brady & Hong, 2006; Cheung, 2004; Torp, Grøgaard, Moen, & Bråtveit, 2005). Conversely, negative peer attitudes towards safety have been observed to engender non-compliance (McIlwain, Gates, & Ciliax, 2008). Although these findings are intuitive, they illustrate the need for organizations to not only motivate workers to follow HPD standards, but also to ensure that leadership behavior reflects these standards.

2.5.2 Organizational Support

Hearing conservation laws have been instituted in many developed countries to protect workers from overexposure to hazardous noise and subsequent hearing loss. In the US, companies are mandated by law to provide HCP services to overexposed individuals, which include supplying adequate HPDs, fitting HPDs and providing training on proper use, conducting routine hearing screenings to assess hearing sensitivity, and other provisions (OSHA, 2008). In addition to the legal aspects of the program, organizations also have a financial incentive to maintain employee health, as the consequences of hearing loss can be detrimental to worker's compensation costs and job productivity. Although hearing conservation requirements may seem onerous, employers are only required to submit to a minimum standard of compliance, which affords some latitude to implement and interpret provisions as they see fit (Lusk et al., 1998). This autonomy can engender innovative and robust HCPs for organizations with sound policies, although loose standards can produce a climate where protective practices are not adhered to consistently. Anticipated disparities in HCP quality have been the motivation for several studies that examined whether company standards and practices had an effect on worker's HPD practices. Similar to the literature examining the role of social support, researchers hypothesized that factors relating to the organization would have an impact on behavior (Bockstael et al., 2013; Cheung, 2004). Multiple findings indicate that perceived organizational support is influential for worker's reported HPD use, with higher usage rates being associated with more nurturing environments. The literature addressing organizational support suggests that promoting worker's awareness of HCP regulations and related company practices is important and likely a significant factor in many worker's preventative behavior.

2.5.3 Variable Noise Exposure

Establishing a reliable work routine can facilitate an individual's attainment of key job-related skills and provide the means for adopting safe work practices. Learning to use HPDs at appropriate intervals is particularly reliant on consistency, given that workers typically lack the discernment necessary to detect when noise exposure thresholds are exceeded and when protection is required (Lusk et al., 1998). The importance of repetitive behavior can be extended to the utility of HPDs, as their effectiveness in preventing noise related hearing loss is highly reliant on continuous use during overexposure (Melamed et al., 1996). Many employees are required to work jobs where their routine and variety of noise are variable, which hinders their efforts to form safe habits (Tak et al., 2009). Two separate studies investigated the potential for variable noise exposure to influence HPD use. In both instances, mean HPD compliance rates were compared between workers who were subject to an alternating schedule, known as shift work, and individuals who worked conventional schedules (Costa & Arezes, 2014; Sam, Anita, Hayati, Haslinda, & Lim, 2016). The shift workers were typically lower level blue collar workers, or managers of such workers, who were exposed to high levels of noise consistently throughout their shift. Whereas, those who worked only normal shifts were skilled workers or supervisors, who were subject to intermittent levels of noise. The two studies observed that shift worker's use was significantly higher than those with conventional schedules, indicating that variable noise levels did influence HPD adherence. A potential explanation for this disparity could be the need for normal shift workers to constantly remove and reinsert their devices throughout the day, which may have been a barrier for some individuals to comply with standards. Disparate HPD behavior between lower level and more senior workers has been observed elsewhere, which lends support for this interpretation (Lusk et al., 1994).

2.5.4 Limitations

There is considerable evidence indicating that environmental factors have an influence on HPD behavior. Considering the wide variety of occupations that are exposed to noise, and the various safety climates those professions generate, this is not a surprising discovery. These findings also support the need for organizations to create a work climate that is supportive of HCP initiatives. While this approach to understanding HPD use was not intended to be comprehensive, there are disadvantages relevant to this issue. For instance, it is unlikely that all worker's behavior is equally influenced by external factors, such as social and organizational influences. In general, all workers within an organization are subject to the same environmental influences, yet there is disparate use. Similarly, the data from shift workers indicated a difference in reported use despite similar exposure (Sam et al., 2016). Based on previously reviewed sources, these differences may be attributed to factors related to physical comfort or beliefs and perceptions, or for reasons that have yet to be considered.

2.6 Summary of Predictors

Motivations for inconsistent HPD use in occupational settings have been examined by many studies from the previously addressed domains. Much of the literature has considered this issue through the lens of behavioral models that draw from social and cognitive theories, while some have studied the role of perceived risk. This cumulative work has uncovered several specific beliefs and perceptions related to protective behavior, which include perceived self-efficacy for using HPDs, perceived benefits of HPDs, perceived risk of hearing loss, perceived barriers for compliance, and others. Additional research has considered the role of factors related to physical comfort, which has established that noise annoyance, noise levels, and physical fit of HPDs are all influential. Finally, variables related to the work environment were speculated to effect behavior. Sources relevant to this approach found that social and organizational influences were significant, as well as variable noise exposure. This collective body of work represents the current knowledge base regarding worker adherence to HPD standards and functions as the foundation for theoretical understanding and intervention efforts. Despite these contributions, there are significant shortcomings that justify further exploration of this area. First, the factors known to influence HPD use are the basis for current interventions, which have not been entirely successful at improving protective behavior. Generally, all US workers exposed to occupational noise are required to be enrolled in an HCP where they are regularly educated on topics relevant to the domains discussed previously and receive other key services intended to reduce hearing loss. Despite ongoing advancements in HCP interventions, HPD technology, and an overall greater public awareness of the dangers of hazardous noise, sources continue to observe substandard compliance (Reddy et al, 2012; Lusk et al, 1995; Edelson et al, 2009). Another limitation is that the literature does not account for the time-inconsistent behavior that is characteristic of intertemporal choices. This is an important omission considering that any disruption in HPD use, and subsequent over-exposure to hazardous noise, can contribute to permanent hearing loss. Given the distant consequences of HPD compliance, some workers are likely to neglect this practice in favor of the more immediate benefits of non-use, which may include improvements in physical comfort, communication, and perceived spatial awareness. Finally, while multiple sources have observed strong relationships between discounting and other previously cited health behaviors, this model has not been applied to HPD use. Considering the hidden dangers and delayed consequences common to HPD compliance and these behaviors, it is likely that HPD use is related to steep discount rates. The purpose of this thesis is to examine whether temporal discount rates are related to HPD compliance.

3.0 Assessing HPD Use

Determining which variables contribute to a given health behavior first requires the use of effective means for measuring the behavior. Utilizing a valid indicator serves many purposes in health research, such as to classify individuals who could benefit from intervention, for developing intervention strategies, and to evaluate intervention success. The present work requires us to consider the available options for assessing HPD use and to select a method that is best suited to separate consistent from inconsistent users. Therefore, the authority to make assertions regarding protective behavior will require a method that is most likely to reflect authentic work behavior in a work setting. In the context of this study, precision will be balanced with validity.

Studies addressing worker HPD compliance have relied on a variety of tactics for assessing behavior. Direct observation has generally been treated as the gold standard indicator and has been the yardstick by which many studies have justified their methods (Lusk, Ronis, & Baer, 1995). This practice seems logical, as *observed* behavior ought to be indicative of *actual* behavior when an observer is not present. The majority of studies evaluating HPD use have relied on self-reported behavior as an indicator, often citing prior research demonstrating high correlation between this measure and direct observation (Lusk, Ronis, & Baer, 1997). Other indicators discussed in the literature include the use of biomarkers, Ecological Momentary Assessment (EMA), video monitoring, and supervisor report (Arezes & Miguel, 2013; Griffin, Neitzel, Daniell, & Seixas, 2009; Van Campen, Murphy, Franks, Mathias, & Toraason, 2002). All of these measures have qualities that validate their utility as a barometer of worker behavior, though there are certain disadvantages unique to each of them that pose a threat to research validity that should first be considered. Each approach will be discussed individually in an effort to establish their suitability for the current study.

3.1.1 Direct Observation

Many scientists believe that observing worker's daily HPD habits is superior to other methods for assessing long-term behavior trends. This notion reasonably assumes that information gathered by directly monitoring limited samples of protective practices more accurately reflects established behavior than information obtained through an indirect means (Suen & Ary, 2014). One advantage of this method as an indicator is its objectivity, which lends itself to greater validity compared to behavior reported by the agent or another source. This approach is also invulnerable to response bias or reporting errors associated with other subjective methods. Despite these advantages, there are certain features that may limit the effectiveness and practicality of this option. First, this measure typically relies on monitoring behavior over relatively small time-intervals. Because of the limited scope, the collected data may not be considered a comprehensive view or reflective of typical behavior (Griffin et al., 2009). Another dilemma is the mandatory presence of research observers at the worksite needed to carry out the assessment. Though this disruption may be benign to some workers, any awareness of being observed during the surveillance process has the potential to sway behavior, likely towards increased compliance (Lusk, Ronis, & Baer, 1995). Finally, direct observation often consists of taking multiple samples of individual workers over several months. Though some of the limitations of this approach can be mitigated through thoughtful study design, the logistical and financial resources required to carry out multiple observations over an extended period may be prohibitive for many studies. Ancillary to the time and manpower required to monitor behavior is gaining access to workers, which is likely to be limited according to the patience and cooperation of company management.

3.1.2 Self-Report

Most of the research addressing HPD compliance has relied on self-reported behavior as an indicator. Self-report measures rely on retrospective accounts from workers related to their HPD habits while performing their jobs. Survey instruments designed for this purpose typically rely on brief questionnaires that establish an individual's rate of HPD use relative to their exposure (Edelson et al., 2009). The self-report method has been favored by many researchers due to its convenience, its ability to quickly gather large amounts of information at a minimal cost, and due to its reportedly high correlation with direct observation (Lusk, Ronis, & Baer, 1995). With these advantages in mind, several studies sought to establish self-reported use as a valid indicator, which are summarized in Table 4.

Table 4. Research addressing validity of self-reported HPD use

Study	Assessment Methods	Self-report Validity
Lusk, Ronis, & Baer (1995)	DO, SVR, SR	Yes. High correlation between SR and DO, not SVR.
Lusk, Ronis, & Kerr (1995)	DO, SR	Yes. High correlation between SR and DO.
Rabinowitz, Weisberg, & Ribak (1996)	DO, SR	Yes. High correlation between SR and DO.
Daniell et al. (2006)	DO, SR	Yes. High correlation between SR and DO.
Edelson et al. (2009)	EMA, SR	Mixed. Fair agreement between SR and EMA.
Griffin et al (2009)	DO, EMA, SR	Mixed. SR correlated with EMA and DO for only steady state noise environments.
Arezes and Miguel (2013)	DO, VM, SR	Yes. No statistically significant differences were observed between assessment methods.

DO = Direct Observation, SVR = Supervisor Report, SR = Self-Report, Ecological Momentary Assessment = EMA, VM = Video Monitoring

Because retrospective reporting requires workers to draw on past experiences, individual accounts of behavior are likely to resemble long-term trends, which qualifies this method as an effective proxy for monitoring behavior over an extended period. Self-reported use has the advantage of not being subject to outside influences that might alter a worker's behavior, such as with direct observations. Further support for this method can be derived from the multiple studies that examined the precision of self-reported health behaviors and observed that individuals generally base self-reported information on the recall of actual events (Palmer et al., 2012; Short et al., 2009). There is also adequate evidence demonstrating a good relationship between direct observation, the supposed gold-standard, and self-reported use, which has contributed to this method's acceptance as a valid indicator of HPD use (Arezes & Miguel, 2013; Daniell et al., 2006; Lusk, Ronis, & Kerr, 1995). Despite these advantages, self-reported data are often seen as being highly susceptible to bias and inaccuracy (McCullagh & Rosemberg, 2015). For instance, a worker may be inclined to report that they are fully compliant to satisfy the expectations of an interviewer, which has been observed in health behaviors studies examining exercise habits and handwashing (Contzen, De Pasquale, & Mosler, 2015; Slootmaker, Schuit, Chinapaw, Seidell, & Van Mechelen, 2009). Others may be indifferent to interviewer perceptions but may misreport use to avoid anticipated sanctions related to their employment. Finally, an inability to recollect past noise exposure beyond a 6-12-month time frame contributes to inaccurate reporting (Bhandari & Wagner, 2006), while one study found accuracy to decline after only a 3-month period (Griffin et al, 2009). However, it is probable that each of these limitations can be successfully mitigated through careful study design. Overall, the ability to obtain information representative of past trends, as well as the avoidance of observer effects, make this an attractive approach for assessing HPD use.

3.1.3 Biomarkers

The use of biomarkers is potentially the least fallible method of assessing health intervention compliance. In the present context, a biomarker refers to a biological manifestation of physical harm or disease as a result of exposure to harmful agents or related to genetic characteristics (McClure, 2002). Biomarkers can be especially useful indicators because they are essentially impervious to bias and reporting error. The effectiveness of biomarkers is heavily dependent on the existence of a reliable technique. High frequency hearing loss has long been accepted as a biomarker of past hazardous noise exposure as this condition is present in a large portion of workers. However, noise-related hearing loss is typically a progressive condition that occurs over an extended period which does not tend to manifest itself in a systematic manner that would render it useful as an indicator of HPD non-compliance (Wilson & McArdle, 2013). Recent work has identified other potential biomarkers related to noise exposure, such as cochlear outer hair cell measurement patterns and stress induced protein production analysis of blood and saliva (Allen, Kennedy, Cryan, Dinan, & Clarke, 2014; Stamper & Johnson, 2015). However, at present the application of these methods as reliable indicators for HPD compliance is only theoretical, meaning that other means should be utilized to determine HPD use.

3.1.4 Ecological Momentary Assessment

Ecological Momentary Assessment (EMA) was established as a measurement technique to increase the precision of retrospective reports of health (Shiffman, Stone, & Hufford, 2008). This approach requires individuals to report their experiences in real-time, reducing the reliance on subject recall, which can be measured across contexts and at varying intervals. Assessments are made while individuals go about their day-to-day activities and can represent a physical or health state, situational factors, symptoms, or even behavior. Prior studies have used this method to assess health related behaviors associated with eating disorders (Stein & Corte, 2003), smoking (Shiffman, 2005), and even HPD use (Edelson et al., 2009; Griffin et al., 2009). Both HPD studies that employed this approach introduced a technique they referred to as activity cards, which served as a reference for comparing self-reported HPD use and direct observation. This protocol measured compliance by requiring workers to record the amount of time HPDs were worn during specific periods of their work shift. During the data collection phase observers took periodic loudness measurements of the worker's environment, while subjects were asked to report HPD use representing 15-minute intervals throughout the day. Both studies observed that behavior recorded on activity cards more closely resembled observed behavior compared to self-reported use alone. In addition, the activity card data were reportedly validated against the direct observation method. These examples portray EMA as an objective measure with high research validity and limited susceptibility to response bias. However, generalizing these findings beyond the bounds of the experiment is problematic due to the highly-controlled manner by which this measurement was applied. For example, requiring workers to record their daily HPD use is a deviation from typical work activity and is not likely to occur outside of the context of a study. This requirement was presumably helpful in urging compliance during the study, but also very likely had an influence on HPD habits. Additionally, data from the activity cards only captured a segment of overall worker behavior over a limited time-period and, therefore may not reflect long-term behavior. Finally, during both studies subjects were informed that though they would be monitored periodically throughout the day and that they should behave as they normally would. This guidance may appear benign but there is strong evidence to suggest that workers tend to be more compliant to safety regulations when they are aware of an observer, an outcome known as the Hawthorne Effect (Srigley, Furness, Baker, & Gardam, 2014). There appears to be evidence to support using EMA as a valid indicator of worker behavior under the structured conditions of an experiment, but data gathered using this procedure may lack the external validity to be generalized to other contexts.

3.1.5 Video Monitoring

Another option for assessing behavior is to use a video monitoring system. This alternative is less commonly discussed in the literature and has only been used by one research group to examine HPD use. Arezes and Miguel (2013) compared the accuracy and reliability of self-reported use and direct observation, against the standard of video monitoring. They utilized existing closed-circuit television (CCTV) systems from the companies they sampled to monitor the HPD habits of several employees over a two-day period. Subjects were monitored over a 15-hour period, representing 2 full work shifts. The analysis concluded that HPD use recorded by direct observation and video monitoring were similar, but that self-reported behavior was slightly overstated. Assuming the workers were not aware of the observations, video monitoring should not have had an influence on worker behavior. Unfortunately, the researchers began the observations by informing the subjects of the study goals and procedures, which presumably would have negated this advantage. Future studies could potentially avoid this oversight by repeating these methods without disclosing their intention to observe HPD behavior. However, video monitoring is generally not a realistic option for conducting research due to the general unavailability of the equipment. The large expense of purchasing and maintaining CCTV type equipment is likely prohibitive for many organizations, and the few that do have it are likely to use this resource to document workplace injuries or for security purposes, in which case access to researchers likely would be limited.

3.1.6 Supervisor Report

One final indicator addressed in the literature is supervisor report. Federal law mandates that employers oversee worker compliance to safety regulations, which confers upon them the stewardship to ensure that workers have access to HPDs and that they are worn with the proper frequency (OSHA, 2008). This requirement should presumably empower supervisors with the awareness to provide a reasonably accurate portrayal of protective behavior trends. Lusk, Ronis, and Baer (1995) examined the contribution of supervisor report, relative to researcher observation and self-reported behavior. In this study, supervisors were interviewed and asked to characterize the HPD use of their employees by reporting the percentage of time they were compliant over a given time frame, relative to self-reported use and direct observations. Large discrepancies were observed between behavior reported by supervisors and the other two methods that led investigators to deem this method as unreliable and, at best, only a rough estimate of general behavior. This finding is not surprising considering the scope of managers' responsibilities and the number of employees under their custody. However, even where supervisors are vigilant and able to provide a credible account, their report of worker behavior is subject to bias. For instance, a manager being questioned about the safety habits of his employees may be unlikely to report unfavorable information to an unfamiliar source. In fact, supervisors may be just as concerned about reporting non-compliance as their employees, out of concern for disciplinary actions and their reputation as a leader. Finally, like self-reported behavior, supervisor's reported use is subject to their ability to recall past events. Ultimately, it is unlikely that the report of a supervisor would be more accurate *and* less biased then reports from the workers, which limit its validity as an indicator of worker behavior.

3.2 HPD Compliance

Prior to assessing worker's HPD habits, it is necessary to characterize optimal behavior. In the pursuit of a comprehensive definition of HPD *compliance*, it is reasonable to assume that few workers are completely non-compliant, meaning no HPD use at all. Given the content and prevalence of HCP training, as well as evidence from prior studies (Edelson et al., 2009), it is more likely that most individuals are at worst part-time or inconsistent users. Removing HPDs to take scheduled breaks or during other intervals of the work day spent away from high noise areas is justified and has no bearing on adherence to protective standards. Moreover, just as complete neglect of HPDs is improbable it is also likely that even the most attentive workers will sporadically remove their devices for short periods, to facilitate communication or for temporary relief from discomfort (Williams, 2009), which might reflect partial compliance. Given the legal directive related to HPDs, a standard that considers non-compliance as *any* protective practices that fall short of continuous use during periods of overexposure to noise would be reasonable (OSHA, 2008). However, applying such a rigid benchmark would likely classify all individuals as non-compliant. In the absence of a universal standard, prior HPD studies have taken various approaches to separate groups according to their patterns of use. For instance, some researchers asked subjects to self-select into one of multiple HPD user groups distinguished by how frequently they felt they used HPDs (e.g., never, seldom, sometimes, always) (Melamed et al., 1996). The distribution of responses was then used to create additional subgroups to classify subjects as *regular*, *occasional,* or *non-users*. Easily the most common classification method observed in the literature required individuals to self-report the percentage of time they wore HPDs when it was required (e.g., 0-100%) on a continuous scale (Lusk et al., 1998). Responses were then coded into a dichotomous outcome of *consistent use* or *inconsistent use* based on a pre-selected threshold. Although this lack of precision may seem problematic, findings from the literature lend credibility to this approach as several prior studies have reported a bimodal distribution of retrospective reports of use (Edelson et al., 2009; Hong & Ronis, 2013; Kim et al., 2010). Other sources acknowledged that while self-report was observed to be a statistically valid measure relative to others, there was a tendency to over report use (Daniell et al., 2006; Lusk, Ronis, & Baer, 1995; Lusk, Ronis, & Baer, 1997). It appears that while workers tend to overstate their use, one can infer that they are generally aware of their HPD habits. Therefore, comparing relatively small differences in reported use may not be meaningful. Considering the evidence provided, measuring HPD use as a propensity for protective behavior, rather than a fixed criterion, may be the more preferred approach.

3.3 Conclusions

Considering the variables associated with assessing adherence to HPD standards, we acknowledge that none are free of limitations or threats to validity. In other words, there is no true gold standard indicator by which to base our verdict. Out of the reviewed options video monitoring appears to be the most objective, the least subject to bias, and would essentially have no influence on worker behavior, assuming observations are carried out anonymously. However, the cost and lack of availability make this an unrealistic option. Even if subjects were selected only from organizations that already possess this resource, gaining the required access would likely be problematic. Both direct observations and EMA have been used in other work and appear to be reliable methods that promote strong internal validity. Yet, the unavoidable presence of research observers required to carry out these measures may influence worker behavior, thus limiting the accuracy of study findings and the ability to generalize to other populations. While EMA can be conducted without observers, the periodic recording of one's own compliance is not common practice and is likely to alter behavior. Additionally, any data gathered using these means only represents a portion of worker's behavior and may not be relevant when compared to a broader time frame. Supervisor and self-report are subjective indicators of HPD use that are allegedly calculated from a long-term surveillance of behavior. Both measures are quick to administer, inexpensive to conduct, and capable of capturing a great deal of data. The literature addressing supervisor report found this approach to be unreliable compared to other measures (Lusk, Ronis, & Baer, 1995), likely related to the limited time and inclination of most managers to monitor their workers, and an aversion to making negative reports regarding workers' behavior. In contrast, self-reported behavior has the potential to be the most reliable indicator, as the data should theoretically be founded on first-hand experiences and the established habits of agents whose behavior is being considered. Because this method relies on a retrospective report, the behavior is also free from observer effects. Finally, there is robust evidence from multiple sources that demonstrate a strong relationship between self-reported use and direct observation, which are listed in Table 5. Two of these studies were particularly useful for lending credibility to self-report as a valid measure, as they clearly explained their methods and were diligent in applying protocols to safeguard validity (Daniell et al., 2006; Lusk, Ronis, & Kerr, 1995). In conclusion, the chief liability of self-reported use appears to derive from the potential for individuals to misreport their behavior due to social desirability bias. However, proper study design and thoughtful instrument development can mitigate this threat to validity, like other survey instruments.

Table 5. Studies reporting strong relationships between self-reported HPD use and direct observation

Study	Assessment Methods	Described Observation Technique
Lusk, Ronis, & Baer (1995)	DO, SVR, SR	Workers observed, then SVR, then SR. No detail of observer technique.
*Lusk, Ronis, & Kerr (1995)	DO, SR	Observers "surreptitiously" recorded workers' use of HPDs.
Rabinowitz, Weisberg, & Ribak (1996)	DO, SR	Very little information provided about technique used.
*Swan et al., (2006)	DO, SR	Workers were observed "unobtrusively" 4 times per day.
Arezes & Miguel (2013)	DO, VM, SR	Subjects were informed about purpose of study before data collection. Observations were carried out periodically over a 15-hour period.

* = Superior observation techniques applied

DO = Direct Observation, SVR = Supervisor Report, SR = Self-Report, Ecological Momentary Assessment = EMA, VM = Video Monitoring

For the current study, the following characteristics are the most desirable: high validity, objective, reflective of long-term health habits, does not influence behavior, and time efficient. Table 6 provides a comparison of each method relative to these provisions. Within the bounds of these criteria video monitoring is superior to all other methods, though it is not available in most cases. Considering the reviewed evidence, self-reported behavior appears to be the most appropriate alternative for separating consistent HPD users from those whose compliance is more casual. Though, the success of this measurement will be contingent on the use of methods and instruments that will limit bias and motivate candid responses.

Table 6. Comparison of HPD behavior indicators

Indicator	**High Validity**	**Objective**	**Long-Term Use**	**No Effect On Behavior**	**Time Efficient**
Direct Observation	Mixed	Yes	No	No	No
Self-report	Mixed	No	Yes	Yes	Yes
Biomarkers	N/A	Yes	N/A	N/A	N/A
Activity Cards	No	Yes	No	No	No
Video Monitoring	Yes	Yes	No	Yes	No
Supervisor Report	No	No	Yes	Yes	Yes

4.0 Intertemporal Choice and Discount Rate Measurement

An intertemporal choice reflects what individuals do when they make trade-offs between costs and benefits occurring at different points in time. The most widely used framework for analyzing intertemporal choice scenarios is derived from discounted utility theory, which assumes that time preferences can be characterized by a single parameter known as the temporal discount rate (Frederick et al., 2002). Individual discount rates represent the degree to which people subjectively devalue future rewards with increased delays. Estimates of individual rates can be derived from field studies of real-world behaviors, or from controlled experiments. Field studies facilitate the observation of behavior in a natural setting from which intertemporal preferences can be inferred (Yao, Mela, Chiang, & Chen, 2012). This approach provides an authentic view of behavioral patterns but it is also subject to multiple confounds, often unrelated to discounting, for which it may be impractical to control. For example, high discount rates implied from seemingly impulsive grocery shopping habits might reflect an individual's preference for a specific brand of food or special dietary requirements, rather than discounting future cost savings. For the current study, we will construct an experimental design to avoid such threats to validity.

A key component of any intertemporal choice experiment is the estimation of discount rates, which is achieved by establishing when an individual is indifferent to a variety of rewards. The indifference point is determined when two or more rewards of varying sizes, received at different intervals, have approximately the same value (Odum, 2011). Despite an abundance of intertemporal choice research, there is little consensus on elicitation techniques and best practices of temporal discounting measures (Hardisty et al., 2013). This is unfortunate given their role as a proxy for the intertemporal choice construct and their overall importance in this type of research.

A review of the literature indicates that most discounting tasks fall into one of two major categories: *choice* and *matching*. A matching task typically presents individuals with two rewards received at different time points, one with a fixed value and one unspecified, and requires them to provide the quantity of that reward that would make them indifferent to the two choices (Attema & Brouwer, 2013). This is essentially a fill in the blank approach to estimating discount rates. Choice based tasks, which are the most commonly utilized method, require individuals to make one or more comparisons between smaller immediate and higher value delayed rewards and to select which option they prefer (Attema & Brouwer, 2013; Hardisty et al., 2013). An individual's pattern of choices can be analyzed and used for discount rate estimation. Both matching and choice-based tasks are suitable methods with distinct advantages. A matching task tends to be less demanding for subjects due to their conceptual relevance. For instance, most participants could readily consider their preferences for experiencing flu symptoms of varying time periods and severity. However, discount rates derived from choice measures, though potentially less intuitive, have historically been better predictors of real-world health outcomes and have less response variation (Attema & Brouwer, 2013; Frederick et al., 2002). Considering the features of these methods, and the environmental characteristics and goals of the current study, we consider a choice-based measure to be the most appropriate approach for eliciting discount rates.

4.1 Choice Tasks

When choice based tasks are applied to health behavior studies, they are primarily confined to either the health or monetary domains (Hardisty et al., 2011). Presenting subjects with hypothetical health scenarios is a transparent approach to assess discounting, as there is an implicit connection between the individual's choices and their implications on time preferences. Task items can target a specific behavior of interest or represent a variety of behaviors. Although health scenarios are conceptually relevant, there are some limitations associated with their use that may threaten validity. For example, because hypothetical health outcomes cannot be honored during an experiment some subjects may not fully immerse themselves in the task, meaning responses may not truly reflect the orientation for future rewards (Chapman et al., 2001). Additionally, task items may represent scenarios with which individuals have little or no inexperience, or potentially a lot of experience, which would presumably contribute to response variability unrelated to discounting. As an alternative, researchers have the option to elicit discount rates by providing subjects with choices related to monetary outcomes. Monetary choices are an effective proxy for eliciting time preferences, as discounting trends can be directly compared to the actual behavior being considered (Lawless et al., 2013). In fact, some studies have observed a greater relationship between health behavior trends and responses to monetary intertemporal choice questions, relative to hypothetical health scenarios (Chapman & Coups, 1999). This finding may be attributed to familiarity, as most individuals have an adequate understanding of the value of money and ample experience making monetary decisions. In contrast, individuals who lack experience or are indifferent to certain health conditions may be incapable of providing a helpful valuation of hypothetical scenarios in the context of an experiment (Chapman et al., 2001). There are likely few adults who are inexperienced or apathetic to financial outcomes.

4.2 Hypothetical Versus Real Monetary Rewards

While some researchers have not observed consistency between health and money for certain intertemporal health choices (Chapman, 1996, 2005), the statistical significance of discount rates elicited from monetary decisions is generally well documented for preventative health behavior studies addressing a variety of health topics (Axon et al., 2009; Daugherty & Brase, 2010; Weller et al., 2008). Experiments that use a monetary choice approach to assess discounting have the option of introducing rewards as hypothetical or as real money to be paid in accordance with an individual's preferences (Johnson & Bickel, 2002). Hypothetical rewards are frequently used instead of real rewards due to potentially large payouts and very long delays that fall outside of a typical study timeline. For instance, honoring a payment of $5000 to be received in 10 years would likely pose a challenge. Another issue could arise if subjects chose to game the system, meaning that in the anticipation of receiving an actual payment they automatically select the highest amount of money offered in favor of providing their true preference. The precision of using hypothetical rewards has naturally been called into question by various groups concerned about whether asking individuals what they *would* prefer is equivalent to experiencing the consequences of their actual choices (Odum, 2011). Unexpectedly, multiple sources observed that the degree of discounting did not differ significantly between real and hypothetical money choice tasks (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003). This evidence suggests that individuals do not seem to view their choices in this context as hypothetical, only the rewards, which further promotes its validity. Additionally, since this task invites subjects to indicate their preferences, there is no obvious right or wrong answer, meaning that they are less likely to be influenced by social desirability (Odum, 2011). The described logistical challenges of honoring scenarios involving real money, as well as the evidence for validity justify using hypothetical monetary rewards for the current study.

4.3 Discounting Measure

In the absence of a standard temporal discount rate measure or guidelines, it is important to select an instrument suitable to the circumstances of the experiment. The intention of the current study is to assess temporal discount rates for individuals who work in a hazardous noise environment, using a choice-based task to present hypothetical monetary rewards. Considering these goals, using an established instrument that has been validated for this purpose will be essential. Various measures have been designed to assess discounting, though few of them have been applied to a health behavior context. Other considerations relate to the study population and environment. Our population will include blue collar workers, many with a limited educational background, with active work schedules, and a finite time to participate in the study. While some prior studies have been granted considerable access and autonomy to work with their population sample (Lusk, Ronis, & Baer, 1997; Lusk et al., 1994), subject contact time and accessibility for the current study will be limited. With these considerations in mind, we intend to use a measure that is intuitive, easily navigable, and relatively quick to administer. Given the limited time and energy available to the participants, an instrument that is overly burdensome may produce insincere responses. It also will be important to avoid sequence effects related to discounting items. Because subjects will be asked to make several choices to complete the task, a non-sequential presentation method of rewards of varying size and delay to receipt will prevent indiscriminate responses or simply choosing the highest value reward. Finally, the measure should be well-established for studying health behaviors, and have evidence of high validity and reliability.

4.4 Monetary Choice Questionnaire

The Monetary Choice Questionnaire (MCQ) was designed by Kirby & Maraković (1996) to assess individual preferences for smaller immediate rewards over delayed larger rewards. This measure introduces a series of hypothetical scenarios that require participants to choose between monetary rewards of varying sizes received at different intervals. The items are presented in a fixed sequence that ensures random presentation of rewards relative to their size, ratio, and delay to receipt, which is essential for engaging subjects to the task unknowingly. This instrument is one of the most widely used for assessing monetary discount rates, it has been validated by a large number of studies involving adults and youth (Duckworth & Seligman, 2005; Epstein et al., 2003; Gray, Amlung, Palmer, & MacKillop, 2016; Kirby et al., 1999), and has high inter-item reliability (α = .98) and good test-retest reliability of .71 (Kirby, 2009). The MCQ is also reasonably quick to administer and does not place a significant mental burden on subjects, which are ideal features for depicting true time preferences (Frederick, 2003) and conducive to the conditions of the current study. Discount rates are calculated according to the following hyperbolic function: $V=A/(1+kD)$. V represents the value of the delayed reward A, at delay D. The k value signifies the rate of discounting, which will vary based on the pattern of choices. The delayed rewards are grouped into three categories based on size, with nine items per category, which include small ($25-$35), medium ($50-$60), and large ($75-$85). Figure 2 illustrates the MCQ item values, intervals of receipt, associated discount rates, and the reward size categories.

Table 7. The Monetary Choice Questionnaire item values, intervals of receipt, associated discount rates, and discounting categories.

	Reward values					
Order	SIR	LDR	Delay	k at indiff	k rank	LDR size
13	$34	$35	186	.00016	1	S
1	$54	$55	117	.00016	1	M
9	$78	$80	162	.00016	1	L
20	$28	$30	179	.00040	2	S
6	$47	$50	160	.00040	2	M
17	$80	$85	157	.00040	2	L
26	$22	$25	136	.0010	3	S
24	$54	$60	111	.0010	3	M
12	$67	$75	119	.0010	3	L
22	$25	$30	80	.0025	4	S
16	$49	$60	89	.0025	4	M
15	$69	$85	91	.0025	4	L
3	$19	$25	53	.0060	5	S
10	$40	$55	62	.0060	5	M
2	$55	$75	61	.0060	5	L
18	$24	$35	29	.016	6	S
21	$34	$50	30	.016	6	M
25	$54	$80	30	.016	6	L
5	$14	$25	19	.041	7	S
14	$27	$50	21	.041	7	M
23	$41	$75	20	.041	7	L

Table 7 continued

7	$15	$35	13	.10	8	S
8	$25	$60	14	.10	8	M
19	$33	$80	14	.10	8	L
11	$11	$30	7	.25	9	S
27	$20	$55	7	.25	9	M
4	$31	$85	7	.25	9	L

***** SIR = smaller, immediate reward; LDR = larger, delayed reward; S, M, and L = the small, medium, and large delayed reward categories; Delay = the delay of the reward in days. k rank = items with the same values of k grouped in ascending rank order. Table reprinted with permission from Kirby et al., (1999).

For the MCQ, values for *k* range from 0.00016 to 0.25 which approximate 1 of 9 different categories, or levels of discounting. Regardless of a subject's choices, their pattern of responses will resemble one of the levels or corresponding k values in this range (See Figure 2). Higher values, or levels, indicate a greater preference for smaller immediate rewards. For carrying out a statistical analysis, the authors recommend either using the level assigned to k or a natural log transformation of the raw scores (K.N. Kirby, personal communication, April 12, 2019). The transformation ensures equal spacing between scores and provides an approximate normal distribution of discount rate classifications.

The MCQ is a conventional instrument for inferring discount rate values from a subject's choices between immediate and delayed rewards. Despite its frequent use, the scoring of discount rates is a complicated process which requires either making a large number of individual algebraic calculations by hand, or the encoding of numerous values and functions into a software database (Kirby, 2000). Although these options are feasible for the determined researcher, their complexity may serve as a barrier to using the MCQ. Kaplan et al., (2016) created a freely available Microsoft Excel-based tool which mitigates the scoring complexities by automatically scoring responses to the MCQ items in accordance with the author's guidelines. The instrument is utilized by entering each of the subject's reward choices into the spreadsheet, "0" for smaller immediate rewards and "1" for larger delayed rewards, which provides a discount rate for each subject based on their pattern of responses. A consistency score for each subject also is provided, which reflects the stability of the pattern of responses relative to the calculated discount rate. A score of less than 75% may be an indication of a lack of attending to the questionnaire. The consistency tool is useful for assessing the veracity of subject responses to other measures. Kaplan and colleagues ensured validity of this instrument by comparing their calculations to those of hand-scored datasets and from values obtained using a spreadsheet programmed according to the specifications of the MCQ authors (Kaplan et al., 2016). This project demonstrated that their instrument matched the hand-scored discount rates up to 10 decimal places and were identical to those measured using a spreadsheet programmed according to the author's instructions.

4.5 Conclusions

Temporal discount rates represent the degree to which individuals prefer immediate, smaller rewards over larger rewards that are received in the future. Various methods have been devised to estimate discount rates for health behavior studies. Despite their extensive use in research, there are few standards or best practices guiding the selection of an appropriate elicitation technique or specific measure. Evidence from previous studies supports the use of a choice-based task that uses hypothetical monetary choices to assess discounting. The MCQ is a valid and reliable instrument with extensive application to health behavior research and will be used in the current study to assess individual discount rates.

5.0 Summary

Occupational noise is an exceptionally common work-related hazard that has been attributed to hearing loss, various adverse health effects, and significant financial liabilities. The effectiveness of the interventions designed to address this health issue are highly reliant on worker adherence to HPD standards. Pervasive neglect of protective behavior has inspired many studies to investigate the motivations behind this trend. Sources have identified influential factors related to physical comfort, beliefs and perceptions related to noise and HPD use, and work-related environmental influences, but none have considered whether non-compliance is related to the devaluing of future hearing health outcomes. Intertemporal choices reflect making decisions that involve tradeoffs between costs and benefits occurring at separate points in time. According to this model, an individual's preferences for rewards of varying size may vary as a function of how soon the rewards are received. The degree to which an individual devalues the receipt of larger delayed rewards in favor of smaller immediate rewards represents their temporal discount rate. Various sources have cited discount rates as reliable predictors of multiple health behaviors. The purpose of this work was to investigate the relationship between individual discount rates and worker compliance to HPDs. The potential predictive relationship between discounting, quantified through responses to hypothetical monetary choices, and self-reported HPD compliance trends was investigated. We examined the collective relationship between discount rates and self-efficacy on HPD use. Findings from this study provide a framework for future studies related to temporal discount rates as a predictor of HPD compliance.

6.0 Research Question, Specific Aims, and Hypothesis

The main objective of the current study was to investigate whether individual temporal discount rates are predictors of HPD compliance for an industrial worker population. Specifically, we examined whether HPD neglect is related to an individual's preference for the immediate rewards of non-use, in favor of the larger benefits of compliance which come delayed. Secondarily, we explored the collective relationships of temporal discounting and self-efficacy related to wearing HPDs. This analysis may provide useful insight into the contributions of these predictors on HPD use.

There is sufficient evidence to support the use of temporal discount rates as indicators of various health behaviors and to assume that HPD use has similarities shared with other intertemporal health choices with known relationships to discounting. Given that temporal discounting has not been considered relative to hearing protective behavior, as well as the gaps in knowledge pertaining to variables related to HPD compliance, the following research question and specific aims were addressed:

Research Question 1: Do individual temporal discount rates predict HPD compliance for an industrial worker population?

Specific Aim 1: Examine the role of intertemporal choice on HPD use for workers exposed to hazardous noise.

Null Hypothesis 1: There is no predictive relationship between discount rates and HPD compliance.

Alternative Hypothesis 1: There is a significant relationship between discount rates and worker's adherence to HPD standards.

Research Question 2: Do temporal discount rates and self-efficacy predict HPD compliance for an industrial worker population?

Specific Aim 2: Explore the relative contributions of self-efficacy and discount rates, relative to HPD compliance.

Null Hypothesis 2: There is no relationship between self-efficacy and discount rates relative to HPD compliance.

Alternative Hypothesis 2: Self-efficacy and discount rates have a significant influence on HPD compliance.

Given the delayed consequences of HPD non-compliance and the hidden dangers of occupational noise we anticipated that less compliant workers would have higher discount rates, such as with other related health behaviors, resulting in a predictive relationship between discounting and HPD use. Additionally, we expected to observe a significant relationship between self-efficacy and compliance consistent with prior literature.

Significance:

The current body of HPD research has not considered whether intertemporal choice has an influence on protective habits for industrial workers. Considering this omission and the predictive relationship between other related health behaviors and discounting, this work will provide a significant contribution to existing theory related to adherence to HPD safety standards. Additionally, if the anticipated relationships are observed, this will provide the basis for new and innovative interventions for improving compliance to HPD standards.

7.0 Materials and Methods

7.1 Research Design

This study used cross-sectional survey data to explore the relationship between temporal discount rates and HPD compliance. A secondary objective examined the collective association between discount rates and self-efficacy relative to HPD compliance. We also included demographic data in the model to investigate potential influences on compliance. Complementary to the main study objectives, we sought to authenticate the study design by examining the associations of cigarette dependence and obesity on discount rates. This inquiry was anticipated to demonstrate a significant association, consistent with prior findings supporting our study design and analysis. Measures used in the study addressed the temporal discounting framework, self-efficacy related to noise exposure and hearing protection use, cigarette dependence, and self-reported HPD use. Demographic information was gathered for descriptive value and for inclusion in the analysis, and self-reported height and weight information were collected to classify obesity. The order of the survey items was consistent for each subject and were arranged according to the following sequence: demographics, discount measure, HPD use, self-efficacy, and smoking dependence. We placed this measure early in the protocol to facilitate genuine participation and to avoid response fatigue, as this instrument required the greatest amount of mental resources. Participants were adult workers who are over-exposed to occupational noise and enrolled in their company HCP. Subjects completed self-guided questionnaires designed to assess their hearing protection habits, temporal discount rate, self-efficacy, smoking and obesity status, and demographics.

7.2 Participants

Convenience sampling was used to recruit 220 study participants from two military medical health clinics in Southeastern Virginia. The sample was taken from a large population of industrial civil servants employed by the U.S. Navy who were over-exposed to occupational noise and subject to federal OSHA hearing conservation regulations (OSHA, 2008). Although both active duty military and civilian workers received care at the medical clinics, only civilian workers were invited to participate in the study. Subjects were included in the study based on their over-exposure to occupational noise, enrollment in their organization HCP, and their ages ranged from 18-65. The upper age limit was imposed to prevent the inclusion of participants with increased risk of age-related hearing loss, which has been observed to influence HPD compliance (Arezes & Miguel, 2008). Individuals were recruited at one of 2 health clinics depending on their place of employment. The populations at both clinics represented workers from a variety of job categories, while only those from Clinic B were from the same work setting.

Subjects were recruited at the health clinic that was geographically located near their workplace. The population from Clinic A originated from a variety of worksites each with presumably unique hearing safety practices and included workers from diverse occupational backgrounds. The Clinic B population also included workers from various job categories, but they were from the same general worksite and were subject to identical safety practices and culture. Individuals from both clinics were subject to daily noise exposures that exceeded OSHA regulated PELs of 85 dBA.

7.3 Procedure

Senior clinic management authorized access to the study populations for both research sites. An on-site research coordinated with the clinical care team to verbally invite individuals who were at the clinic to receive an annual hearing screening to participate in the study. Those who conceded were introduced to the researcher and brought to a separate space where they were given a brief description of the study and informed of their obligation as participants. Subjects were notified that they were participating in a hearing loss prevention study that required completion of a 5-8-minute self-guided survey to solicit some demographic information, health-related questions, and would require them to make several choices regarding money. Individuals were informed that participation was voluntary and they could withdraw at any time. No identifying information was solicited or collected, and subjects were assured anonymity pertaining to their responses to encourage candid participation in the survey. The researcher remained present to hand out paper surveys, to answer clarifying questions, and to verify completion of the entire protocol. No further assistance or guidance was provided. Individuals who completed the survey were given $5 cash for their participation, regardless of the pattern of their responses. Data collection was performed over the span of 2 weeks and represented a normal work time-period. Subjects presented to the research site at random on their own volition and were not encouraged by the research team to visit the clinic during the study.

7.3.1 Demographic Questionnaire

A self-directed, multi-choice item format was used to measure the participant's age, gender, ethnicity, and years of hazardous noise work experience. Workers also were asked to write their estimated height in feet and inches and their current estimated weight in pounds based on their most recent annual occupational health assessment. The height and weight information was used to assess obesity, which is described later in the document.

7.3.2 Discount Rates

Individual discount rates were assessed using the Monetary Choice Questionnaire (MCQ) (Kirby & Maraković, 1996), as part of the experiment protocol (See Appendix A). This measure provided subjects with a series of 27 hypothetical scenarios presented non-sequentially, in which they were required to choose between a smaller, immediate monetary reward and a larger, delayed reward. For example, “Would you rather have $34 today, or $50 in 30 days?” The items were presented in a fixed sequence for all subjects, which ensured random presentation of the rewards relative to their size, ratio, and delay to receipt. The seemingly unsystematic arrangement of choices was consistent with the author’s recommendations (Kirby, 2000) and was fundamental to engaging subjects to the task and promoting authentic responses. The MCQ delayed rewards pertaining to one of three categories based on the size of the rewards, with nine items per category, which included small ($25-$35), medium ($50-$60), and large ($75-$85). The participant’s pattern of responses resulted in a discount rate ranging between 0.00016 and 0.25, with higher values indicating a greater preference for smaller immediate rewards. Responses were entered into a Microsoft Excel-based MCQ tool described previously (Kaplan et al., 2016), which produced the subject’s discount rate, or k value. A natural log transformation of the measured k values was used to carry out the statistical analysis. Discount rates functioned as the primary predictor variable.

7.3.3 HPD Use

Worker's HPD compliance served as the dependent variable and was represented by the self-reported percentage of time (0-100%) they used hearing protection. The subjects were asked to indicate how often they used HPDs when they were in their work areas when it was required during three time periods: 1. The past week, 2. The past month, and 3. The past 3 months. The mean value of the sum reported for each interval was calculated to represent the subject's compliance rate. This approach has been validated previously, has been observed to correlate with a direct observation method, and has been applied extensively in the HPD literature (Lusk, Ronis, & Baer, 1995). For the analysis, we used a median split to dichotomize responses into high and low compliance groups, which was coded as 0 or 1, respectively. This method differs from prior studies which have largely applied arbitrary thresholds to define compliance, as there is no evidence to support a specific standard. A variety of other compliance thresholds, both above and below the median, were tested to assess the sensitivity of our approach.

7.3.4 Perceived Self-Efficacy

Self-efficacy has been observed as one of the most influential health-related beliefs and perceptions for forecasting HPD compliance (Lusk, Ronis, & Hogan, 1997). In the context of the current study, self-efficacy referred to an individual's perception of their ability to properly use HPDs in an occupational setting. The Self-Efficacy of Use of Hearing Protection scale was employed to measure this construct (See Appendix B). This 10-item instrument was developed by Lusk et al., (1997) and has been applied extensively to HPD related research. The widespread application of this tool has illustrated its high content validity, and its reliability has exhibited a

Spearman-Brown reliability coefficient of .82 (Lusk, Ronis, & Baer, 1997; Lusk, Ronis, & Kerr, 1995). A sample question is: “I can use hearing protection correctly.” All items were measured on a 6-point Likert scale in the following manner: 1= Strongly Disagree; 2=Moderately Disagree; 3=Slightly Disagree; 4=Slightly Agree; 5=Moderately Agree; 6=Strongly Agree. Individual scores were represented as the mean of the sum of total responses, which ranged from 1 (low self-efficacy) to 6 (high self-efficacy).

7.3.5 Smoking and Obesity

There is considerable evidence to suggest that individuals who make unhealthy decisions tend to have higher discount rates than those with more wholesome habits. Nicotene addiction and obesity have been among the most closely linked to high discount rates (Barlow et al., 2016; Lawless et al., 2013), and also tend to be common health traits among the current study population (Proper & Hildebrandt, 2010; Sorensen, Barbeau, Hunt, & Emmons, 2004). This established relationship provided rationale for inclusion in the study protocol as a method of ensuring the sample was representative of past findings and to verify the integrity of our design. Participants were evaluated for their smoking status using the Cigarette Dependence Scale (CDS-5), a 5-item scale that measures the magnitude of nicotine dependence to cigarettes (Etter, Le Houezec, & Perneger, 2003) (Refer to Appendix C). This scale is widely used in research, is relatively quick to administer, non-burdensome to subjects, includes non-smokers, and has high test-retest reliability (r=.77) and good internal consistency (Cronbach’s α=.84). Survey items inquired about the participant’s relationship to cigarettes by requiring them to assign a number to their perceived degree of dependence and specific cigarette habits, or by rating their dependence on a 5-point Likert scale. The mean of the sum of individual scores were used to assign a dependency rating, which ranged from 1 (low dependency) to 5 (high dependency).

Height and weight information was obtained to calculate participant's estimated Body Mass Index (BMI). Individuals were asked to self-report their estimated height in feet and inches and their current estimated weight in pounds based on measurements taken from their most recent occupational health physical. Participants with a BMI of 30 or higher were considered obese, in accordance with the Center for Disease Control and Prevention (CDC) guidelines (Centers for Disease Control and Prevention, 2018). The CDC growth chart for children and teens was used to calculate the weight percentile for the relatively few subjects younger than 20 years of age. The BMI calculation was performed by dividing the subject's weight in pounds by height in inches, squared, and multiplying by a conversion factor of 703 (e.g., BMI = weight (lb) / $[\text{height (in)}]^2$ x 703). Participants were placed in dichotomized groups based on their status as *obese* or *not obese*.

7.4 Data Analysis

The median self-reported HPD compliance served as a binary dependent variable for the primary and secondary analyses. Predictor variables included discount rates and age, which were continuous, and binary classifications of self-efficacy and gender. Demographic data for race and years of experience were included in the descriptive data summary. Both obesity and smoking dependence were binary outcomes which were utilized to authenticate past findings of high discount rates for obese and smoking individuals. To address Specific Aim 1 of examining the role of intertemporal choice on HPD use for workers exposed to hazardous noise, we used a binary logistic regression model to analyze the relationship between discount rates and HPD compliance. We also explored other classifications of compliance in the same manner, using thresholds both above and below the median, to assess the influence on the model. A binary logistic regression model also was used to evaluate Specific Aim 2, which sought to explore the relative influence of self-efficacy and discount rates relative to HPD compliance. The model was then expanded to include all the predictor variables to examine their relationship on the dependent variable. Finally, we used multiple non-parametric tests to assess mean group differences for all the variables used in the analysis, given that our samples were derived from 2 distinct populations.

All statistical analyses were performed using IBM SPSS version 24. A power analysis was conducted using G*Power version 3.1 to determine an appropriate sample size. Using a two-tailed test with a significance level of 5%, and assuming 80% power to detect a small effect size of 2.5 (Chen, Cohen, & Chen, 2010) between groups, the preferred sample size is 176. We sampled 220 workers to afford higher resolution to our analysis.

7.5 Study Design Rationale

We have made a robust effort to construct our study according to sound theory and underlying evidence, although in some respects our methods reflect an effort to balance proper study design with practical considerations. While we do consider this work to be well designed, it is useful to discuss potential concessions that may have been made given our circumstances. Some aspects of our approach that could be perceived as compromised concern our study population, the HPD compliance assessment method, our limited use of known predictors of HPDs, and our use of hypothetical monetary rewards for eliciting discount rates.

7.5.1 Population

Our study sample was taken from 2 separate populations of workers with disparate characteristics. Although care was taken to ensure all subjects met the study criteria, the population from Clinic A was a somewhat random group from varied occupations, with presumably disparate noise exposure, and from different work environments. While the Clinic B population was from the same worksite, they also came from a variety of jobs with unique occupational environments. Using a more controlled population of workers would be more ideal, as this approach might lend itself to more meaningful data and generalization of findings. Unfortunately, more exclusive access to workers could not be obtained for this project. Future studies could improve on our work by building the relationships needed to recruit a more homogenous sample of participants.

7.5.2 HPD Assessment Method

Our review of the literature discussed the importance of utilizing an effective method for assessing compliance to HPD standards. We also illustrated the available approaches for measuring this behavior, which included direct observation, self-report, video monitoring, biological markers, EMA, and supervisor report. The evidence suggests that biomarkers are not currently feasible, while supervisor report is less reliable than other available measures. EMA using activity cards has been observed to be effective, but results may not generalize beyond the context of a study given its influence on protective behavior. Both direct observation and self-report have been used extensively and are found to be reliable sources of information, assuming comprehensive methods are utilized. The most objective approach with the least opportunity for bias is video monitoring. Unfortunately, this option is only accessible in very limited circumstances given the high cost to employers and the limited availability to researchers. For the current study, we utilized self-reported HPD use to assess compliance given its ease of use, lack of influence on subject behavior, and superior ability to capture long-term behavior. This method is also highly reliable assuming response bias can be properly addressed.

7.5.3 Known Predictors of HPD Use

One limitation we faced with the current population is limited time with the subjects. Because our only access to the subjects was combined with a medical appointment, which was mitigated by clinic staff, our window for participation was considerably limited. The varied amount of data that we desired to obtain, as well as the relatively small incentive to participate required a timely approach. We reviewed the many variables known to influence HPD behavior, such as perceived benefit, perceived risk, and self-efficacy. Because of our limited window for interaction we opted to select the most commonly observed factor, which was self-efficacy. While our circumstances did not prevent us from using additional measures, we sought to encourage sincere subject participation by avoiding response fatigue. The instrument we used to assess the self-efficacy construct was highly reliable, validated by many studies, and was relatively quick to administer (Lusk, Ronis, & Baer, 1997). Future studies could improve on our design by utilizing more of the identified variables known to predict HPD use to provide a more comprehensive view of their relative influences on this behavior.

7.5.4 Hypothetical Monetary Rewards

One final perceived concession from our study design was our decision to utilize hypothetical monetary rewards for measuring discount rates. It is reasonable to assume that individuals would respond differently to being offered real money rewards to ones that are not authentic. Surprisingly, the evidence strongly supports using hypothetical money as there are no significant differences in discount rates elicited from the two methods (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden et al., 2003). The implication is that while individuals perceive the money as hypothetical, they consider their choices to be genuine. Some potential downfalls of using real money include individuals gaming the system by only choosing the largest payout, and the logistical challenges involved with honoring potentially large payments far into the future. While using hypothetical rewards has the potential to induce apathy to the discounting measure, we consider this to be preferable to the pitfalls related to paying real money. To mitigate the potential for insincere participation, we will assess reliability scoring for monetary choices, which will detect random response patterns (Kaplan et al., 2016).

7.5.5 Summary

We concede that aspects of our study design choices may be perceived as being preferential towards practical considerations over theoretical integrity. While some decisions were influenced by the circumstances of our study, we uphold that our design largely followed evidence from the literature. Table 7 provides a summary of some aspects of our study that could be improved in a future study.

Table 8. Components related to the study design and rationale

Study Component	Ideal	Current Study	Rationale
Population	Randomized, controlled for key study variables	Similar populations, limited control	No access to controlled population
HPD Assessment Method	Video Monitoring	Self-Reported Use	Video Monitoring not realistic
Predictors of HPD Use	All known predictors	Only self-efficacy	Limited time with subjects
Monetary Rewards	Real or Hypothetical	Hypothetical	Good evidence for hypothetical rewards

8.0 Results

We surveyed a total of 220 subjects from the 2 research sites. Two individuals were excluded from participating due to their age exceeding the study criteria. Four participants were removed from the analysis because they did not complete the discounting measure, and 2 were removed due to unacceptable reliability related to responses on the discounting measure (Kaplan et al., 2016). Thus, 214 total subjects were included in the analysis. The accuracy of transcribed scores was reviewed by a research assistant unfamiliar with the process or purpose of the study. The assistant reviewed 10% of the surveys and confirmed 100% accuracy.

8.1 Sample Characteristics

Table 8 shows the subject demographic characteristics, discounting scores, self-efficacy, and self-reported HPD compliance by group from each site. No significant differences between samples were found for gender, χ^2 (2, N=214) =2.74, p= .098; age, U =5412.0, p =.756; discount rates, U =5182.5, p =.337; self-efficacy χ^2 (2, N=214) =.407, p =.524, and HPD compliance χ^2 (2, N=214) =2.25, p =.134. We accounted for this parity by analyzing both samples as 1 larger sample in our analysis. Race and years of experience also were measured for descriptive purposes. The majority of participants were White (66%), followed by Black (28%), Hispanic/Latino (3%), while American Indians, Asians, and other races each made up less than 1%. Work experience ranged from less than 1 year (7%), 1-10 years (47%), 11-20 years (23%), and greater than 20 years (23%).

Table 9. Demographic characteristics, discount rates, self-efficacy, and health data for both groups

Characteristics	Clinic A	Clinic B	All Subjects
Gender			
Male	73	107	180
Female	19	15	34
Age in years (mean)	37.8	38.5	38
Discount rates (mean)	.033	.041	.038
Compliance (mean)	87	81	84
Self-efficacy			
High	44	53	97
Low	48	69	117
Smoking Dependency			
High	16	24	40
Low	76	98	174
Obese			
Yes	29	57	86
No	63	65	128

*Compliance represents the mean reported use percentage by group. Self-efficacy and smoking data are characterized by *high* versus *low* self-efficacy and smoking dependency respectively.

8.2 Predictors of HPD Compliance

A natural log transformation of the measured k values was used to analyze the relationship of discount rates to the dependent variable. A single predictor logistic regression model was fitted to the data to test the research hypothesis that discount rates are predictors of HPD compliance. The predictive association between DR and compliance did not meet strict statistical compliance when they were combined in a single model, (OR = .760, p = .159). We repeated the model using alternate HPD compliance thresholds both above and below the median reported use to assess the sensitivity of our classification of compliance (Table 8). We fluctuated the compliance cut-off to 100% (OR = .799, p = .262), 95% (OR = .759, p =.160), 75% (OR = .679, p = .096), and 50% (OR = .924, p = .584). None of these scenarios resulted in statistical significance.

Self-efficacy was dichotomized into *high* versus *low* for our analysis based on individual scores relative to the mean. An additional logistic regression model assessed the collective influence of discount rates and self-efficacy relative to compliance. Discounting was not meaningful but the addition of self-efficacy demonstrated a significant predictive relationship, (OR = 3.14, p<.001). On average, workers with high self-efficacy related to using HPDs have 3.14 higher odds of being compliant relative to those with low self-efficacy. The model was extended to include discounting, self-efficacy, gender, and age. Both self-efficacy and gender (OR = 2.35, p<.05) were significant, while age was not. A summary of the output related to predictors of HPD compliance are provided in Table 9.

Table 10. Logistic regression analysis output for the relationship between discounting, self-efficacy, and demographics relative to HPD compliance

Predictor Variables	Dependent Variable	Odds Ratio	p
DR	Compliance 90%	.760	.159
DR	Compliance 100%	.799	.262
DR	Compliance 95%	.759	.160
DR	Compliance 75%	.679	.096
DR	Compliance 50%	.924	.584
Self-efficacy***	Compliance 90%	3.14	.00006
Gender****	Compliance 90%	2.35	.039
Age	Compliance 90%	1.016	.186

*Compliance denotes HPD compliance threshold applied to the model

**DR = Discount Rates, ***p<.001, ****p<.05

8.3 Smoking and Obesity as Predictors of Discounting

Smoking dependence scores were dichotomized into high versus low due to very skewed mean scores from very few smokers in the sample. Therefore, individuals who smoked were considered to have high smoking dependence, while non-smokers had low dependence. Participants were either obese or not obese based on self-reported height and weight values. We used 2 separate logistic regression models to assess discount rates relative to these characteristics. Discounting (OR = 1.827, p<.05) was a significant predictor of smoking dependence, indicating that high smoke dependent individuals have 1.83 greater odds of having a higher discount rate than non-smokers. Discounting did not present a meaningful relationship (OR = 1.303, $p = .343$) relative to obesity.

9.0 Discussion

In the present study, we explored the potential role of intertemporal choice in an industrial worker's tendency to comply with occupational HPD standards from a health economic perspective. We employed a recognized temporal discounting measure using hypothetical monetary scenarios in which participants chose between smaller immediate rewards and larger delayed rewards. A subsequent goal was to consider the collective relationship between temporal discounting and self-efficacy on HPD compliance, and to consider the prospective significance of demographic characteristics on compliance. We developed a novel, self-guided survey protocol to measure temporal discount rates, self-efficacy related to wearing HPDs, age, and gender. Temporal discount rates were not a significant predictor of HPD compliance when the median self-reported usage rate was the threshold. We examined the influence of using multiple compliance cut-offs above and below the median reported rate and again observed no statistical significance. Self-efficacy was a significant predictor for HPD use, as we anticipated, and was higher for more compliant individuals. Females were also more compliant than males, while age was not significant. An additional analysis of discount rates on smoking and obesity indicated that those who smoke have higher discount rates than non-smokers, while there was no meaningful relationship with obesity. We also examined the parity of our study populations by evaluating group mean differences related to the characteristics assessed in the models and found no significant differences between sample groups.

9.1 Discount Rates and Compliance

Using HPDs in an occupational setting involves costs and benefits that occur at separate points in time. Therefore, it is reasonable to expect that preferences for receiving future health rewards would have some relationship with the likelihood of presently engaging in preventive behavior. Yet, the current study indicates that temporal discount rates are not significant predictors of HPD compliance, despite evidence of a statistical relationship with other preventive health behaviors (Axon et al., 2009; Bradford, 2010; Daugherty & Brase, 2010; Van Der Pol et al., 2017). These findings were not entirely unforeseen as some studies of preventative behavior have reported only a small relationship (Chapman et al., 2001; Chapman & Coups, 1999), while others observed no statistical significance (Chapman, 1998, 2005). One explanation offered for this discrepancy is that temporal discounting might play only a marginal, yet significant role in decision making for preventative behavior relative to other contributors. This interpretation may have relevance to our study as various sources have observed HPD behavior to be multifaceted with several influential factors (Lusk, Ronis, & Hogan, 1997). Our review of the literature identified multiple variables that impact this behavior related to the physical comfort, beliefs and perceptions, and environmental factors domains. Considering the diversity of contributors to protective HPD behavior, it may be reasonable to consider the relevance of a statistically significant variable with a small effect size. This approach is supported by other sources that have considered variables that influence HPD use and have observed statistical significance with small effects (Kim et al., 2010; McCullagh et al., 2010). Although the present study was adequately powered to capture a meaningful relationship of 2.5 (Chen et al., 2010), with sufficient resolution to capture an odds ratio of 1.4 under the study parameters, the absence of an association between discount rates and compliance may be attributable to a lack of statistical power which could be uncovered with a larger sample size. Because we had no prior knowledge of what the effect size might be, we may have overestimated the odds ratio to what would be needed to detect a meaningful effect. A future study could explore the statistical significance of an increased sample size.

Another reason we did not detect a meaningful relationship could be related to the higher overall compliance we observed in our sample relative to other studies. The 84% mean reported compliance rate from the current study is considerably higher than the reported rates of 41% (Edelson et al., 2009), 62% (Daniell et al., 2006), and as high as 70% (Lusk, Ronis, & Baer, 1995) stated from other sources. Additionally, our compliance data were disproportionately skewed towards higher adherence, which differs from some of the bimodal distributions reported previously (Edelson et al., 2009; Hong & Ronis, 2013; Kim et al., 2010). Although we classified compliance by splitting the median reported use in our sample, the presumably steeper discount rates produced by less compliant workers from another sample could produce an opposing outcome in the regression model. The current study population was anticipated to be equivalent to other US workers in the manufacturing domain, considering they are subject to the same federal hearing conservation regulations, and their employers likely have an equal incentive to manage an effective program to reduce worker's compensation costs. The precise reasons for the disparity in compliance are unknown as only limited personal data were collected, though potential sources of variability in our sample relative to others could include higher average noise levels (Melamed et al., 1992), greater accessibility to a variety of HPDs (e.g., greater comfort, acceptance) (Shohet & Bent, 1998), or less tangible differences related to hearing conservation culture (Cheung, 2004). There is no evidence to suggest compliance *should* systematically be higher among military employed civilian workers compared to other groups, but future studies might consider this possibility.

One measurement issue may offer an alternative explanation for no statistical significance. Our approach of measuring temporal discounting rates using a choice based measure requiring subjects to make hypothetical monetary choices between rewards of varying size and time of receipt was well justified given the advantages and conditions of our study (Johnson & Bickel, 2002). The MCQ is a highly valid and reliable instrument, and it allowed for reasonably quick administration, placed limited burden on subjects, and was an intuitive task for our population. Despite our calculated approach to the current study, the scenario of receiving future rewards of varying sizes and times may not have been similar enough to the mental calculation used to make HPD decisions. It is well documented that disparate discounting tasks can produce varying outcomes based on differences, such as the size of rewards and time of receipt (Attema, 2012), whether rewards are presented as gains or losses (Chapman, 1996), and the method of elicitation (e.g., matching versus choice task) (Attema & Brouwer, 2013; Hardisty et al., 2013). Because individuals do not have one discount rate for all scenarios, there is no standard measure that can be applied to all contexts. Thus, it is possible that temporal discounting applied to the MCQ monetary scenarios are not those applied to HPD behavior. Despite an abundance of intertemporal choice research, there is little consensus on elicitation techniques and best practices of temporal discounting measures (Hardisty et al., 2013). Given that the current study is a first look at the relationship between discount rates and HPD compliance, it may be valuable to examine this association using multiple elicitation methods.

Finally, the fact that discount rates were not related to preventative HPD behavior might indicate that HPD use is not an intertemporal choice and that workers do not view their present behavior as a trade-off for future health. This possibility would suggest that some classes of behaviors reflect temporal discounting while others do not. Sources have generally observed higher discount rates when individuals are in a *hot* state (e.g., hunger, sexual arousal) compared to a *cold* state (e.g., calm, not aroused) (Chapman, 2005; Lawless et al., 2013). For instance, behaviors such as risky sex, smoking, and illicit drug use, have generally produced stronger statistical significance compared to medication adherence and exercise. Some sources have suggested that this difference is mitigated by the visceral elements related to hot behaviors (Chapman et al., 2001; Reimers, Maylor, Stewart, & Chater, 2009). In general, preventative behaviors have been less commonly associated with discount rates, relative to health activities that promote a physical response or those with an addictive component (Chapman, 2005). While there are data to support a relationship between discounting and several preventative behaviors, the evidence is still lacking for HPD compliance. Findings from the current study support characterizing HPD use as a preventative behavior, rather than a risky or addictive activity, in the context of intertemporal choice theory.

9.2 Self-Efficacy and Compliance

Our secondary research goal was to consider the relative contributions of discount rates and self-efficacy on compliance. Although we did not observe a relationship with discounting in our study, self-efficacy is a significant predictor of compliance in all our models, which was expected considering the strength of previous findings (Lusk, Ronis, & Hogan, 1997; Lusk et al., 1994; Melamed et al., 1996). One reason for this portion of the analysis was to weigh how much of the variance would be ascribed to discounting relative to a known predictor. While no such comparison could be made, our findings did bolster our study in two ways. First, we authenticated our research protocol, as an opposing finding would have suggested potential pitfalls in our methodological approach. Secondly, we broadened the literature related to the predictive relationship between self-efficacy and HPD behavior.

9.3 Age, Gender, and Compliance

Our models indicate that gender is a significant predictor of compliance, while age is not. Neither trait has been systematically observed in the literature to influence hearing protective behavior, but there is some evidence to support the role of gender (Lusk, Ronis, & Baer, 1997). The odds ratio indicates that females are 2.4 times more likely to adhere to HPD requirements than males, which suggests that tailoring HCP interventions based on gender may be effective. One potential weakness to this inference relates to the limited personal data collected from the subjects. Specific occupational information could not be obtained given our methodology, therefore, the differences we observed may be related to job type. For instance, while our methods ensured that only individuals who were overexposed to occupational noise were included in the study, there may have been other factors that influenced HPD habits, such as variable exposure to noise (Costa & Arezes, 2014) or differences in loudness levels (Melamed et al., 1994). We recognize that this limitation may affect generalization of our findings and suggest future studies account for job type when considering HPD compliance between genders.

9.4 Smoking and Obesity on Discount Rates

To ensure our sample was representative of prior discounting literature, we sought to establish a predictive relationship between discount rates relative to smoking status and obesity. Our data indicate that discounting is a significant predictor of smoking dependence, which is consistent with previously reported literature, and that smokers have 1.83 higher odds of having a higher discount rate than non-smokers. Surprisingly, discounting is not related to obesity. Around 40% of our subjects were classified as obese, which coincides with past report of worker populations (Santos & Barros, 2003; Viester, Verhagen, Bongers, & van der Beek, 2015). One reason our data does not reflect the literature on discounting and obesity may be related to population differences in our study relative to other evidence. Industrial workers may differ in their tendency to forgo future rewards relative to, for example, the general adult population from the United States (Zhang & Rashad, 2008) or Japan (Ikeda, Kang, & Ohtake, 2010), college psychology students (Weller et al., 2008), or clinically identified obese women (Davis, Patte, Curtis, & Reid, 2010). Because workers in the manufacturing domain are subject to periodic occupational health assessments and are regularly admonished regarding health-related behavior, they also may be more future oriented regarding their health than other populations. Currently, these differences are difficult to assess because of the lack of discounting literature with an industrial worker population (Sigurdsson, Taylor, & Wirth, 2013). Although obesity studies have generally reported meaningful effect sizes, studies that elicited discount rates using monetary rewards versus another approach generally observed smaller levels of significance (Barlow et al., 2016). However, methodological differences observed across obesity studies have made quantitative comparisons problematic. Given these challenges and the absence of discounting literature on worker populations, the body of literature could be strengthened by future studies.

9.5 Worker Populations

We compared the populations from both clinics to establish parity for analyzing all subjects as one sample. The data support evaluating both groups as one population as there were no significant mean differences in our samples associated with the primary study characteristics. This was a concern for the current study considering the many known differences that can influence worker HPD habits relevant to our populations, such as work safety culture (Kim et al., 2010) and noise levels (Melamed et al., 1994). Our findings support broadening inclusion criteria when conducting studies using noise exposed personnel. Although it is desirable to control for population specific variables, this may be problematic due to limited access to such groups. Also, within a given occupational entity, there tends to be significant variety in job duties and noise exposure (Edelson et al., 2009). Even when access to a common class of workers is attained, there is likely individual variety that may be difficult to account for, and certainly varying amounts of sound attenuation depending on HPD insertion proficiency (Neitzel, Somers, & Seixas, 2006). Essentially, noise exposure is highly individual.

9.6 Defining HPD Compliance

One challenge we faced in designing our study was determining a working definition for HPD compliance. Using HPDs 100% of the time while working in noise would be the ideal standard and would certainly meet federal requirements (OSHA, 2008), though the evidence suggests that this criterion would likely exclude many individuals who fall short of this mark but are diligent in their protective habits (Edelson et al., 2009; Lusk, Ronis, & Baer, 1995). Prior studies have largely applied arbitrary thresholds to define compliance as there is no evidence to support a specific standard. From a biological standpoint, noise induced hearing loss occurs as a function of sound pressure (e.g., intensity) and duration of the exposure, as well as genetic predisposing factors (Rabinowitz, 2012; Wilson & McArdle, 2013). There is no calculation to determine exactly how much unprotected noise exposure will cause hearing loss, but there is evidence to support that a greater degree of adherence leads to better hearing outcomes (Davies et al., 2008; Groenewold et al., 2014). In the absence of a true standard, we split self-reported HPD use at the median to define compliance. We also tested our model using thresholds above and below the median to investigate the influence on the outcome and to provide evidence for a gold standard threshold. We assessed the influence of using 100%, 95%, 75%, and 50% as a standard for compliance, which were both slightly above and well below the 90% median reported use. Although one can argue against considering 75% or 50% as *compliant*, assessing these values in the model allowed us to observe the effects of fluctuating this variable to extreme limits. Our results indicated that temporal discount rates were not significant predictors of compliance at any of the tested standards. In other words, adjusting the standard for compliance had no influence on the relationship between discounting and compliance, even when we varied the threshold above and well below the median. Although the data bares no statistical significance on our primary research inquiry, given the lack of influence on the outcome we consider this finding as support for using the median to analyze compliance in the current study. Generalizing this approach to other studies will require further evidence.

10.0 Conclusions

Various sources have reported a relationship between temporal discount rates and unhealthy behavior. Our study is the first to investigate the association of discounting on HPD compliance for industrial workers. We also examined whether self-efficacy and demographic data were related to compliance. Adjacent to our primary goals, we sought to authenticate prior data showing a relationship of discount rates on smoking and obesity, as well as confirm parity between our study populations. We applied a self-guided survey embedded with various instruments to collect the study data, including a discounting measure that required subjects to make a series of hypothetical monetary choices. Our analysis concluded that in the current study discounting was not related to compliance. However, we did observe a significant relationship between self-efficacy and compliance, which is consistent with the hearing conservation and occupational health literature. Compliance related to our subject demographics is significant for gender, with females being more than twice as likely to be compliant, while age was not predictive. The gender specific findings align with some prior studies and support the use of tailored interventions. We did substantiate prior literature showing significance between discounting and smoking, but discount rates were not related to obesity. This discrepancy may be related to population differences of our subjects relative to other studies. Finally, our evaluation of the two study samples demonstrated parity which allowed us to analyze all subjects as one population and supports broadening the inclusion criteria for worker populations in HPD studies. Our research provides the framework for future work investigating the role of intertemporal choice with the following adjustments: adequately powered to detect a very small effect size, utilizing multiple discounting elicitation methods, and drawing from a variety of worker domains to assess differences in discount rates.

Prospective studies also may consider employing a model that includes all the predictors discussed in this work pertaining to the physical comfort, beliefs and perceptions, and environmental factors domains.

Appendix A

Monetary-Choice Questionnaire

For each of the next 27 choices, please indicate which reward you would prefer: the smaller reward today, or the larger reward in the specified number of days.

1. Would you prefer $54 today, or $55 in 117 days?
2. Would you prefer $55 today, or $75 in 61 days?
3. Would you prefer $19 today, or $25 in 53 days?
4. Would you prefer $31 today, or $85 in 7 days?
5. Would you prefer $14 today, or $25 in 19 days?
6. Would you prefer $47 today, or $50 in 160 days?
7. Would you prefer $15 today, or $35 in 13 days?
8. Would you prefer $25 today, or $60 in 14 days?
9. Would you prefer $78 today, or $80 in 162 days?
10. Would you prefer $40 today, or $55 in 62 days?
11. Would you prefer $11 today, or $30 in 7 days?
12. Would you prefer $67 today, or $75 in 119 days?
13. Would you prefer $34 today, or $35 in 186 days?
14. Would you prefer $27 today, or $50 in 21 days?
15. Would you prefer $69 today, or $85 in 91 days?
16. Would you prefer $49 today, or $60 in 89 days?
17. Would you prefer $80 today, or $85 in 157 days?
18. Would you prefer $24 today, or $35 in 29 days?
19. Would you prefer $33 today, or $80 in 14 days?
20. Would you prefer $28 today, or $30 in 179 days?
21. Would you prefer $34 today, or $50 in 30 days?
22. Would you prefer $25 today, or $30 in 80 days?
23. Would you prefer $41 today, or $75 in 20 days?
24. Would you prefer $54 today, or $60 in 111 days?
25. Would you prefer $54 today, or $80 in 30 days?
26. Would you prefer $22 today, or $25 in 136 days?
27. Would you prefer $20 today, or $55 in 7 days?

Appendix B

Self-Efficacy of Use of Hearing Protection Scale

1. I need to learn more so that I can use hearing protection effectively.

ValueLabel

1	***strongly disagree***
2	***moderately disagree***
3	***slightly disagree***
4	***slightly agree***
5	***moderately agree***
6	***strongly agree***
7	

2. I can use hearing protection correctly.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

3. I do not always use my hearing protection the way it should be used.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

4. I know how to use my hearing protection so that it works effectively.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

5. I do everything possible to make my hearing protection work effectively.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

6. I am sure that I can use hearing protection correctly.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

7. I am sure that I can ask for help if I have difficulty using hearing protection.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

8. I am not sure I can tell if my hearing protection is working effectively.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

9. I am sure I can talk with someone while using my hearing protection.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

10. I am sure I can use my hearing protection so it works effectively.

ValueLabel

1strongly disagree
2moderately disagree
3slightly disagree
4slightly agree
5moderately agree
6strongly agree

Appendix C

The Cigarette Dependence Scale, 5-item short version (CDS-5), English-language version

Questions	Response options	Recoding
1.Please rate your addiction to cigarettes on a scale of 0 to 100: - I am NOT addicted to cigarettes at all = 0 - I am extremely addicted to cigarettes = 100	___ Addiction	0-20 = 1 21-40 = 2 41-60 = 3 61-80 = 4 81-100 = 5
2.On average, how many cigarettes do you smoke per day?	___ Cigarettes / day	0-5 = 1 6-10 = 2 11-20 = 3 21-29 = 4 30+ = 5
3.Usually, how soon after waking up do you smoke your first cigarette?	___ Minutes	0-5 = 5 6-15 = 4 16-30 = 3 31-60 = 2 61+ = 1
4.For you, quitting smoking for good would be:	Impossible = 5 Very difficult = 4 Fairly difficult = 3 Fairly easy = 2 Very easy = 1	No recoding
Please indicate whether you agree with the following statement:		
5.After a few hours without smoking, I feel an irresistible urge to smoke	Totally disagree = 1 Somewhat disagree = 2 Neither agree nor disagree = 3 Somewhat agree = 4 Fully agree = 5	

Bibliography

Affairs, V. (2017). *Fiscal Year 2016 Annual Benefits Report: Compensation Section*. Retrieved from http://www.benefits.va.gov/REPORTS/abr/A BR-Co mpensation-FY16-0613017.pdf.

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes, 50*(2), 179-211.

Allen, A. P., Kennedy, P. J., Cryan, J. F., Dinan, T. G., & Clarke, G. (2014). Biological and psychological markers of stress in humans: focus on the Trier Social Stress Test. *Neuroscience & Biobehavioral Reviews, 38,* 94-124.

Arezes, P., & Miguel, S. (2013). Assessing the use of hearing protection in industrial settings: A comparison between methods. *International Journal of Industrial Ergonomics, 43*(6), 518-525.

Arezes, P. M., & Miguel, A. S. (2002). Hearing protectors acceptability in noisy environments. *Annals of Occupational Hygiene, 46*(6), 531-536.

Arezes, P. M., & Miguel, A. S. (2005a). Hearing protection use in industry: The role of risk perception. *Safety Science, 43*(4), 253-267.

Arezes, P. M., & Miguel, A. S. (2005b). Individual perception of noise exposure and hearing protection in industry. *Human Factors, 47*(4), 683-692.

Arezes, P. M., & Miguel, A. S. (2008). Risk perception and safety behaviour: A study in an occupational environment. *Safety Science, 46*(6), 900-907.

Attema, A. E. (2012). Developments in time preference and their implications for medical decision making. *Journal of the Operational Research Society, 63*(10), 1388-1399.

Attema, A. E., & Brouwer, W. B. (2013). In search of a preferred preference elicitation method: A test of the internal consistency of choice and matching tasks. *Journal of Economic Psychology, 39*, 126-140.

Axon, R. N., Bradford, W. D., & Egan, B. M. (2009). The role of individual time preferences in health behaviors among hypertensive adults: a pilot study. *Journal of the American Society of Hypertension, 3*(1), 35-41.

Bade, R., & Parkin, M. (2007). *Foundations of economics*: Pearson/Addison Wesley.

Baker, F., Johnson, M. W., & Bickel, W. K. (2003). Delay discounting in current and never-before cigarette smokers: similarities and differences across commodity, sign, and magnitude. *Journal of abnormal psychology, 112*(3), 382.

Barlow, P., Reeves, A., McKee, M., Galea, G., & Stuckler, D. (2016). Unhealthy diets, obesity and time discounting: a systematic literature review and network analysis. *obesity reviews, 17*(9), 810-819.

Bhandari, A., & Wagner, T. (2006). Self-reported utilization of health care services: improving measurement and accuracy. *Medical Care Research and Review, 63*(2), 217-235.

Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: delay discounting in current, never, and ex-smokers. *Psychopharmacology, 146*(4), 447-454.

Bockstael, A., De Bruyne, L., Vinck, B., & Botteldooren, D. (2013). Hearing protection in industry: Companies' policy and workers' perception. *International Journal of Industrial Ergonomics, 43*(6), 512-517.

Bradford, W. D. (2010). The association between individual time preferences and health maintenance habits. *Medical Decision Making, 30*(1), 99-112.

Brady, J., & Hong, O. (2006). Hearing Protection: Work climate and hearing protection behaviors in construction workers. *Professional Safety, 51*(11), 18.

Centers for Disease Control and Prevention, C. (2018, August 24, 2018). Disability and Obesity. Retrieved from https://www.cdc.gov/ncbddd/disabilityandhealth/obesity.html.

Chapman, G. B. (1996). Temporal discounting and utility for health and money. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(3), 771.

Chapman, G. B. (1998). The Psychology of Intertemporal Choice *Psychology of Learning and Motivation: Advances in Research and Theory* (pp. 83-113): Academic Press San Diego.

Chapman, G. B. (2005). Short-term cost for long-term benefit: time preference and cancer control. *Health psychology, 24*(4S), S41.

Chapman, G. B., Brewer, N. T., Coups, E. J., Brownlee, S., Leventhal, H., & Levanthal, E. A. (2001). Value for the future and preventive health behavior. *Journal of Experimental Psychology: Applied, 7*(3), 235.

Chapman, G. B., & Coups, E. J. (1999). Time preferences and preventive health behavior: acceptance of the influenza vaccine. *Medical Decision Making, 19*(3), 307-314.

Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Communications in Statistics—Simulation and Computation®, 39*(4), 860-864.

Chesson, H. W., Leichliter, J. S., Zimet, G. D., Rosenthal, S. L., Bernstein, D. I., & Fife, K. H. (2006). Discount rates and risky sexual behaviors among teenagers and young adults. *Journal of Risk and uncertainty, 32*(3), 217-230.

Cheung, C.-k. (2004). Organizational influence on working people's occupational noise protection in Hong Kong. *Journal of safety research, 35*(4), 465-475.

Contzen, N., De Pasquale, S., & Mosler, H.-J. (2015). Over-reporting in handwashing self-reports: Potential explanatory factors and alternative measurements. *PloS one, 10*(8), e0136445.

Costa, S., & Arezes, P. (2014). *The influence of shift work in the use of hearing protection devices.* Paper presented at the Proceedings of the European Safety and Reliability Conference (ESREL 2013).

Daniell, W. E., Swan, S. S., McDaniel, M. M., Camp, J. E., Cohen, M. A., & Stebbins, J. G. (2006). Noise exposure and hearing loss prevention programmes after 20 years of regulations in the United States. *Occupational and environmental medicine, 63*(5), 343-351.

Daniell, W. E., Swan, S. S., McDaniel, M. M., Stebbins, J. G., Seixas, N. S., & Morgan, M. S. (2002). Noise exposure and hearing conservation practices in an industry with high incidence of workers' compensation claims for hearing loss. *American journal of industrial medicine, 42*(4), 309-317.

Daugherty, J. R., & Brase, G. L. (2010). Taking time to be healthy: Predicting health behaviors with delay discounting and time perspective. *Personality and Individual differences, 48*(2), 202-207.

Davies, H., Marion, S., & Teschke, K. (2008). The impact of hearing conservation programs on incidence of noise-Induced hearing loss in Canadian workers. *American journal of industrial medicine, 51*(12), 923-931.

Davis, C., Patte, K., Curtis, C., & Reid, C. (2010). Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. *Appetite, 54*(1), 208-213.

Duckworth, A. L., & Seligman, M. E. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological science, 16*(12), 939-944.

Edelson, J., Neitzel, R., Meischke, H., Daniell, W., Sheppard, L., Stover, B., & Seixas, N. (2009). Predictors of hearing protection use in construction workers. *Annals of Occupational Hygiene, 53*(6), 605-615.

Ellenbecker, M. J. (1996). Engineering controls as an intervention to reduce worker exposure. *American journal of industrial medicine, 29*(4), 303-307.

Epstein, L. H., Richards, J. B., Saad, F. G., Paluch, R. A., Roemmich, J. N., & Lerman, C. (2003). Comparison between two measures of delay discounting in smokers. *Experimental and clinical psychopharmacology, 11*(2), 131.

Etter, J.-F., Le Houezec, J., & Perneger, T. V. (2003). A self-administered questionnaire to measure dependence on cigarettes: the cigarette dependence scale. *Neuropsychopharmacology, 28*(2), 359.

Ferrer, R. A., & Klein, W. M. (2015). Risk perceptions and health behavior. *Current opinion in psychology, 5*, 85-89.

Frederick, S. (2003). Measuring intergenerational time preference: Are future lives valued less? *Journal of Risk and uncertainty, 26*(1), 39-53.

Frederick, S., Loewenstein, G., & O'donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of economic literature, 40*(2), 351-401.

Gray, J. C., Amlung, M. T., Palmer, A. A., & MacKillop, J. (2016). Syntax for calculation of discounting indices from the monetary choice questionnaire and probability discounting questionnaire. *Journal of the experimental analysis of behavior, 106*(2), 156-163.

Green, L., Fristoe, N., & Myerson, J. (1994). Temporal discounting and preference reversals in choice between delayed outcomes. *Psychonomic Bulletin & Review, 1*(3), 383-389.

Griffin, S. C., Neitzel, R., Daniell, W. E., & Seixas, N. S. (2009). Indicators of hearing protection use: self-report and researcher observation. *Journal of occupational and environmental hygiene, 6*(10), 639-647.

Groenewold, M. R., Masterson, E. A., Themann, C. L., & Davis, R. R. (2014). Do hearing protectors protect hearing? *American journal of industrial medicine, 57*(9), 1001-1010.

Hardisty, D., Fox-Glassman, K., Krantz, D., & Weber, E. (2011). How to measure discount rates? An experimental comparison of three methods.

Hardisty, D. J., Thompson, K. F., Krantz, D. H., & Weber, E. U. (2013). How to measure time preferences: An experimental comparison of three methods. *Judgment and Decision Making, 8*(3), 236-249.

Hong, O., Lusk, S. L., & Ronis, D. L. (2005). Ethnic differences in predictors of hearing protection behavior between Black and White workers. *Research and theory for nursing practice, 19*(1), 63-76.

Hong, O., & Ronis, D. L. (2013). Predictors of hearing protection behavior among firefighters in the United States. *International journal of behavioral medicine, 20*(1), 121-130.

Hsu, Y.-L., Huang, C.-C., Yo, C.-Y., Chen, C.-J., & Lien, C.-M. (2004). Comfort evaluation of hearing protection. *International Journal of Industrial Ergonomics, 33*(6), 543-551.

Hutchison, T. L. S., T. Y. (2014). *Hearing Conservation Manual*: Council for Accreditation in Occupational Hearing Conservation.

Ikeda, S., Kang, M.-I., & Ohtake, F. (2010). Hyperbolic discounting, the sign effect, and the body mass index. *Journal of health economics, 29*(2), 268-284.

Irle, H., Rosenthal, C., & Strasser, H. (1999). Influence of a reduced wearing time on the attenuation of hearing protectors assessed via temporary threshold shifts. *International Journal of Industrial Ergonomics, 23*(5-6), 573-584.

Janz, N. K., & Becker, M. H. (1984). The health belief model: A decade later. *Health education quarterly, 11*(1), 1-47.

Jarmolowicz, D. P., Lemley, S. M., Asmussen, L., & Reed, D. D. (2015). Mr. right versus Mr. right now: a discounting-based approach to promiscuity. *Behavioural processes, 115*, 117-122.

Johnson, M. W., & Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *Journal of the experimental analysis of behavior, 77*(2), 129-146.

Johnson, M. W., Johnson, P. S., Herrmann, E. S., & Sweeney, M. M. (2015). Delay and probability discounting of sexual and monetary outcomes in individuals with cocaine use disorders and matched controls. *PloS one, 10*(5), e0128641.

Jones, C. L., Jensen, J. D., Scherr, C. L., Brown, N. R., Christy, K., & Weaver, J. (2015). The health belief model as an explanatory framework in communication research: exploring parallel, serial, and moderated mediation. *Health communication, 30*(6), 566-576.

Kalampakorn, S. (2000). *Stages of construction workers' use of hearing protection.*

Kaplan, B. A., Amlung, M., Reed, D. D., Jarmolowicz, D. P., McKerchar, T. L., & Lemley, S. M. (2016). Automating scoring of delay discounting for the 21-and 27-item monetary choice questionnaires. *The Behavior Analyst, 39*(2), 293-304.

Kerr, M. J., Lusk, S. L., & Ronis, D. L. (2002). Explaining Mexican American workers' hearing protection use with the health promotion model. *Nursing research, 51*(2), 100-109.

Kim, Y., Jeong, I., & Hong, O.-S. (2010). Predictors of hearing protection behavior among power plant workers. *Asian nursing research, 4*(1), 10-18.

Kirby, K. (2000). Instructions for inferring discount rates from choices between immediate and delayed rewards. *Unpublished manuscript, Williams College*.

Kirby, K. N. (1997). Bidding on the future: Evidence against normative discounting of delayed rewards. *Journal of Experimental psychology: general, 126*(1), 54.

Kirby, K. N. (2009). One-year temporal stability of delay-discount rates. *Psychonomic Bulletin & Review, 16*(3), 457-462.

Kirby, K. N., & Maraković, N. N. (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. *Psychonomic Bulletin & Review, 3*(1), 100-104.

Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *Journal of Experimental psychology: general, 128*(1), 78.

Lagorio, C. H., & Madden, G. J. (2005). Delay discounting of real and hypothetical rewards III: Steady-state assessments, forced-choice trials, and all real rewards. *Behavioural processes, 69*(2), 173-187.

Lawless, L., Drichoutis, A. C., & Nayga, R. M. (2013). Time preferences and health behaviour: a review. *Agricultural and Food Economics, 1*(1), 17.

Leather, P., Beale, D., & Sullivan, L. (2003). Noise, psychosocial stress and their interaction in the workplace. *Journal of Environmental Psychology, 23*(2), 213-222.

Lusk, S. L., & Kelemen, M. J. (1993). Predicting use of hearing protection: A preliminary study. *Public Health Nursing, 10*(3), 189-196.

Lusk, S. L., Kerr, M. J., & Kauffman, S. A. (1998). Use of hearing protection and perceptions of noise exposure and hearing loss among construction workers. *Am Ind Hyg Assoc J, 59*(7), 466-470.

Lusk, S. L., Ronis, D. L., & Baer, L. M. (1995). A comparison of multiple indicators observations, supervisor report, and self-report as measures of workers' hearing protection use. *Evaluation & the Health Professions, 18*(1), 51-63.

Lusk, S. L., Ronis, D. L., & Baer, L. M. (1997). Gender differences in blue collar workers' use of hearing protection. *Women & health, 25*(4), 69-89.

Lusk, S. L., Ronis, D. L., & Hogan, M. M. (1997). Test of the health promotion model as a causal model of construction workers' use of hearing protection. *Research in nursing & health, 20*(3), 183-194.

Lusk, S. L., Ronis, D. L., & Kerr, M. J. (1995). Predictors of hearing protection use among workers: Implications for training programs. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(3), 635-640.

Lusk, S. L., Ronis, D. L., Kerr, M. J., & Atwood, J. R. (1994). Test of the Health Promotion Model as a causal model of workers' use of hearing protection. *Nursing research, 43*(3), 151-157.

Madden, G. J., Begotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and clinical psychopharmacology, 11*(2), 139.

Masterson, E. A., Themann, C. L., Luckhaupt, S. E., Li, J., & Calvert, G. M. (2016). Hearing difficulty and tinnitus among US workers and non-workers in 2007. *American journal of industrial medicine, 59*(4), 290-300.

McClure, J. B. (2002). Are biomarkers useful treatment aids for promoting health behavior change?: An empirical review. *American journal of preventive medicine, 22*(3), 200-207.

McCullagh, M., Lusk, S. L., & Ronis, D. L. (2002). Factors influencing use of hearing protection among farmers: A test of the Pender health promotion model. *Nursing research, 51*(1), 33-39.

McCullagh, M., Ronis, D., & Lusk, S. (2010). Predictors of use of hearing protection among a representative sample of farmers. *Research in nursing & health, 33*(6), 528-538.

McCullagh, M., & Rosemberg, M. (2015). Social Desirability Bias in Self-Reporting of Hearing Protector Use among Farm Operators. *Ann Occup Hyg, 59*(9), 1200-1207. doi:10.1093/annhyg/mev046.

McIlwain, D. S., Gates, K., & Ciliax, D. (2008). Heritage of army audiology and the road ahead: The Army Hearing Program. *American journal of public health, 98*(12), 2167-2172.

Melamed, S., & Bruhis, S. (1996). The effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability: a controlled field experiment. *Journal of Occupational and Environmental Medicine, 38*(3), 252-256.

Melamed, S., Luz, J., & Green, M. (1992). Noise exposure, noise annoyance and their relation to psychological distress, accident and sickness absence among blue-collar workers--the Cordis Study. *Israel journal of medical sciences, 28*(8-9), 629-635.

Melamed, S., Rabinowitz, S., Feiner, M., Weisberg, E., & Ribak, J. (1996). Usefulness of the protection motivation theory in explaining hearing protection device use among male industrial workers. *Health psychology, 15*(3), 209.

Melamed, S., Rabinowitz, S., & Green, M. S. (1994). Noise exposure, noise annoyance, use of hearing protection devices and distress among blue-collar workers. *Scandinavian journal of work, environment & health*, 294-300.

Merriam-Webster. (2004). *Merriam-Webster's collegiate dictionary*: Merriam-Webster.

Morata, T. C., Fiorini, A. C., Fischer, F. M., Krieg, E. F., Gozzoli, L., & Colacioppo, S. (2001). Factors affecting the use of hearing protectors in a population of printing workers. *Noise and Health*, *4*(13), 25.

Murray-Johnson, L., Witte, K., Patel, D., Orrego, V., Zuckerman, C., Maxfield, A. M., & Thimons, E. D. (2004). Using the extended parallel process model to prevent noise-induced hearing loss among coal miners in Appalachia. *Health Education & Behavior, 31*(6), 741-755.

Neitzel, R., Somers, S., & Seixas, N. (2006). Variability of real-world hearing protector attenuation measurements. *Ann Occup Hyg, 50*(7), 679-691.

Nelson, D. I., Nelson, R. Y., Concha-Barrientos, M., & Fingerhut, M. (2005). The global burden of occupational noise-induced hearing loss. *American journal of industrial medicine, 48*(6), 446-458.

Odum, A. L. (2011). Delay discounting: I'm ak, you're ak. *Journal of the experimental analysis of behavior, 96*(3), 427-439.

Oliveira-Castro, J. M., & Marques, R. S. (2017). Temporal Discounting and Marketing Variables: Effects of Product Prices and Brand Informational Reinforcement. *The Behavior Analyst*, *40*(2), 475-492.

Orji, R., Vassileva, J., & Mandryk, R. (2012). Towards an effective health interventions design: an extension of the health belief model. *Online journal of public health informatics, 4*(3).

Occupational safety and health standards: Occupational Noise Exposure. Standard 29 CFR 1910.95., (2008).

OSHA. (2017). Occupational Noise Exposure: Overview.   Retrieved from https://www.osha.gov/S LTC/noisehe aringconservation.

Palmer, L., Johnston, S. S., Rousculp, M. D., Chu, B.-C., Nichol, K. L., & Mahadevia, P. J. (2012). Agreement between internet-based self-and proxy-reported health care resource utilization and administrative health care claims. *Value in Health, 15*(3), 458-465.

Patel, D. S., Witte, K., Zuckerman, C., Murray-Johnson, L., Orrego, V., Maxfield, A. M., Thimons, E. D. (2001). Understanding barriers to preventive health actions for occupational noise-induced hearing loss. *J Health Commun, 6*(2), 155-168. doi:10.1080/10810730120042.

Popova, L. (2012). The extended parallel process model: Illuminating the gaps in research. *Health Education & Behavior, 39*(4), 455-473.

Prince, M. M., Stayner, L. T., Smith, R. J., & Gilbert, S. J. (1997). A re-examination of risk estimates from the NIOSH Occupational Noise and Hearing Survey (ONHS). *The Journal of the Acoustical society of America, 101*(2), 950-963.

Proper, K. I., & Hildebrandt, V. H. (2010). Overweight and obesity among Dutch workers: differences between occupational groups and sectors. *International archives of occupational and environmental health, 83*(1), 61.

Quick, B. L., Stephenson, M. T., Witte, K., Vaught, C., Booth-Butterfield, S., & Patel, D. (2008). An examination of antecedents to coal miners' hearing protection behaviors: A test of the theory of planned behavior. *Journal of safety research, 39*(3), 329-338.

Rabinowitz, P. M. (2000). Noise-induced hearing loss. *American family physician, 61*(9), 2759-2760.

Rabinowitz, P. M. (2012). The Public Health Significance of Noise-Induced Hearing Loss. *40*, 13-25. doi:10.1007/978-1-4419-9523-0_2.

Raymond, D. M., Hong, O., Lusk, S. L., & Ronis, D. L. (2006). Predictors of hearing protection use for Hispanic and non-Hispanic White factory workers. *Research and theory for nursing practice*, *20*(2), 127-140.

Raymond III, D. M., & Lusk, S. L. (2006). Testing decisional balance and self-efficacy applied to workers' use of hearing protection. *Nursing research, 55*(5), 328-335.

Reddy, R. K., Welch, D., Thorne, P., & Ameratunga, S. (2012). Hearing protection use in manufacturing workers: A qualitative study. *Noise and Health, 14*(59), 202.

Reimers, S., Maylor, E. A., Stewart, N., & Chater, N. (2009). Associations between a one-shot delay discounting measure and age, income, education and real-world impulsive behavior. *Personality and Individual differences, 47*(8), 973-978.

Ronis, D. L., Hong, O., & Lusk, S. L. (2006). Comparison of the original and revised structures of the health promotion model in predicting construction workers' use of hearing protection. *Research in nursing & health, 29*(1), 3-17.

Royster, L., Royster, J., Driscoll, D., & Layne, M. (2003). Hearing protection devices. *The Noise Manual*, 379.

Sam, W., Anita, A., Hayati, K., Haslinda, A., & Lim, C. (2016). Shift work as a predictor of hearing protection devices use among manufacturing workers in selangor, Malaysia. *International Journal of Public Health and Clinical Sciences*, *3*(2), 67-76.

Santos, A.-C., & Barros, H. (2003). Prevalence and determinants of obesity in an urban sample of Portuguese adults. *Public health, 117*(6), 430-437.

Sbihi, H., Teschke, K., Macnab, Y. C., & Davies, H. W. (2010). Determinants of use of hearing protection devices in Canadian lumber mill workers. *Annals of Occupational Hygiene, 54*(3), 319-328.

Scott, J. (2000). Rational choice theory. *Understanding contemporary society: Theories of the present, 129*.

Seixas, N. S., Neitzel, R., Stover, B., Sheppard, L., Daniell, B., Edelson, J., & Meischke, H. (2011). A multi-component intervention to promote hearing protector use among construction workers. *International Journal of Audiology, 50*(sup1), S46-S56.

Shiffman, S. (2005). Dynamic influences on smoking relapse process. *Journal of personality, 73*(6), 1715-1748.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annu. Rev. Clin. Psychol., 4*, 1-32.

Shohet, J. A., & Bent, T. (1998). Hearing loss: The invisible disability: Helping patients overcome a stigma of old age. *Postgraduate medicine, 104*(3), 81-90.

Short, M. E., Goetzel, R. Z., Pei, X., Tabrizi, M. J., Ozminkowski, R. J., Gibson, T. B., Wilson, M. G. (2009). How accurate are self-reports? An analysis of self-reported healthcare utilization and absence when compared to administrative data. *Journal of occupational and environmental medicine/American College of Occupational and Environmental Medicine, 51*(7), 786.

Sigurdsson, S. O., Taylor, M. A., & Wirth, O. (2013). Discounting the value of safety: Effects of perceived risk and effort. *Journal of safety research, 46*, 127-134.

Slootmaker, S. M., Schuit, A. J., Chinapaw, M. J., Seidell, J. C., & Van Mechelen, W. (2009). Disagreement in physical activity assessed by accelerometer and self-report in subgroups of age, gender, education and weight status. *International Journal of Behavioral Nutrition and Physical Activity, 6*(1), 17.

Sorensen, G., Barbeau, E., Hunt, M. K., & Emmons, K. (2004). Reducing social disparities in tobacco use: a social-contextual model for reducing tobacco use among blue-collar workers. *American journal of public health, 94*(2), 230-239.

Stamper, G. C., & Johnson, T. A. (2015). Auditory function in normal-hearing, noise-exposed human ears. *Ear and hearing, 36*(2), 172.

Stein, K. F., & Corte, C. M. (2003). Ecologic momentary assessment of eating-disordered behaviors. *International Journal of Eating Disorders, 34*(3), 349-360.

Story, G., Vlaev, I., Seymour, B., Darzi, A., & Dolan, R. (2014). Does temporal discounting explain unhealthy behavior? A systematic review and reinforcement learning perspective. *Frontiers in behavioral neuroscience, 8*, 76.

Suen, H. K., & Ary, D. (2014). *Analyzing quantitative behavioral observation data*: psychology press.

Suter, A. H. (2002). *Hearing conservation manual*: Council for Accrediation in Occupational Hearing Conservation.

Tak, S., Davis, R. R., & Calvert, G. M. (2009). Exposure to hazardous workplace noise and use of hearing protection devices among US workers—NHANES, 1999–2004. *American journal of industrial medicine, 52*(5), 358-371.

Tate, L. M., Tsai, P.-F., Landes, R. D., Rettiganti, M., & Lefler, L. L. (2015). Temporal discounting rates and their relation to exercise behavior in older adults. *Physiology & behavior, 152*, 295-299.

Teuscher, U., & Mitchell, S. H. (2011). Relation between time perspective and delay discounting: A literature review. *The Psychological Record, 61*(4), 613-632.

Torp, S., Grøgaard, J. B., Moen, B. E., & Bråtveit, M. (2005). The impact of social and organizational factors on workers' use of personal protective equipment: a multilevel approach. *Journal of Occupational and Environmental Medicine, 47*(8), 829-837.

Van Campen, L. E., Murphy, W. J., Franks, J. R., Mathias, P. I., & Toraason, M. A. (2002). Oxidative DNA damage is associated with intense noise exposure in the rat. *Hearing Research, 164*(1-2), 29-38.

Van Der Pol, M., Hennessy, D., & Manns, B. (2017). The role of time and risk preferences in adherence to physician advice on health behavior change. *The European Journal of Health Economics, 18*(3), 373-386.

Verbeek, J. H., Kateman, E., Morata, T. C., Dreschler, W. A., & Mischke, C. (2012). Interventions to prevent occupational noise-induced hearing loss. *Cochrane Database of Systematic Reviews*(10).

Viester, L., Verhagen, E. A., Bongers, P. M., & van der Beek, A. J. (2015). The effect of a health promotion intervention for construction workers on work-related outcomes: results from a randomized controlled trial. *International archives of occupational and environmental health, 88*(6), 789-798.

Weller, R. E., Cook III, E. W., Avsar, K. B., & Cox, J. E. (2008). Obese women show greater delay discounting than healthy-weight women. *Appetite, 51*(3), 563-569.

Williams, W. (2009). Is it reasonable to expect individuals to wear hearing protectors for extended periods? *International Journal of Occupational Safety and Ergonomics*, *15*(2), 175-181.

Wilson, R. H., & McArdle, R. (2013). Characteristics of the audiometric 4,000 Hz notch (744,553 veterans) and the 3,000, 4,000, and 6,000 Hz notches (539,932 veterans). *Journal of Rehabilitation Research & Development*, *50*(1).

Yao, S., Mela, C. F., Chiang, J., & Chen, Y. (2012). Determining consumers' discount rates with field studies. *Journal of Marketing Research*, *49*(6), 822-841.

Zhang, L., & Rashad, I. (2008). Obesity and time preference: the health consequences of discounting the future. *Journal of biosocial science*, *40*(1), 97-113.