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The Utilization and Validation of the Human Factors Intervention Matrix and the Companion Assessment Tool FACES in the Development of Novel Interventions

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By

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SIGNATURE PAGE

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DEDICATION

This dissertation is dedicated to my incredible parents, Noelle and Richard.

I love you.

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When I think about my time at Embry-Riddle Aeronautical University, the saying “It takes a village…” comes to mind. This has been a long but incredible journey, and I am very grateful for everyone who has helped me get to where I am today!

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ABSTRACT

The purpose of the current project was to utilize and validate the Human Factors Intervention Matrix (HFIX) and the companion assessment tool FACES regarding developing and ranking novel interventions. This was completed by 1. Uncovering whether brainstorming with HFIX generated a higher quantity, quality, and broader breadth of ideas compared to traditional brainstorming, and 2. Seeing whether the modality in which HFIX was utilized affected the quantity, quality, and breadth of ideas generated. This research employed a 2x2 between-subjects experimental design (n = 120) where participants were assigned to groups of three in one of the four conditions. Analyses indicated that the HFIX brainstorming group (i.e., F2F/H condition) generated more interventions than the other three conditions. Regarding quality, results discovered that brainstorming with HFIX produced more feasible, acceptable, and sustainable interventions than participants utilizing the traditional brainstorming technique. Finally, results show that using HFIX to facilitate idea generation during the brainstorming process increased the number of interventions generated in the environment category for the F2F/H group. Implications of these results and considerations for future research are discussed. This work has provided a foundation for future research to continue exploring the effect that HFIX and FACES have on the idea generation process.

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DEFINITIONS OR NOMENCLATURE

IGTs	(Idea generation techniques)
Quantity	Number of unique ideas generated
Quality	How good the ideas generated are at solving the proposed problem
HFACS	(Human Factors Analysis and Classification System)
HFIX	(Human Factors Intervention Matrix)
FACES	(Feasibility, Accessibility, Cost, Effectiveness, Sustainability)
VC	Videoconferencing
F2F	Face to Face
MANOVA	Multivariate Analysis of Variance

Chapter One
Introduction

On June 14th, 2016, Nebraskans Matt and Melissa Graves, alongside their two children, Lane (2 years old) and Ella (4 years old), were vacationing at Disney's Grand Floridian Resort and Spa when their lives were changed forever. After a fun-filled day in the parks, the family decided to go to the Seven Seas Lagoon beach to watch "Zootopia." While waiting for the movie to begin, Lane, alongside other children, was collecting water in buckets from the lake to make sandcastles on the beach. Lane was ankle-deep in the water, bent down to fill his bucket when suddenly, an alligator burst out of the water and administered a devastating bite to his head. Matt heard the splash and when he saw what was happening, immediately jumped into the water to try and pry open the alligator's mouth. Unfortunately, Matt could not pull his son free, and the alligator dragged Lane deep into the murky lagoon. A massive search ensued, and Lane's lifeless body was recovered 16 hours later (Visser, 2016).

That which began as a typical fun-filled family vacation at Walt Disney World (WDW) in June 2016 ended in tragedy. The unthinkable had happened… An alligator attacked and killed a two-year-old boy in the Seven Seas Lagoon at the "Happiest Place on Earth." The news of this accident spread like wildfire and left people questioning how this could have happened and what could be done to prevent this from happening again in the future.

Fortunately, companies and organizations like Disney have a suite of tools at their disposal that can be utilized to detect key components of the system that have failed or are failing. One method in that arsenal that could be used involves employing frameworks that specifically focus on system safety, such as Root Cause Analysis (RCA; Rooney & Vanden Hauvel, 2004), Fault tree analysis (FTA; Lee et al., 1985), and the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegmann, 2000). These system safety frameworks reliably analyze incidents and help to identify the underlying human factors issues that contributed to the accident (Cohen et al., 2005; Ergai et al., 2015). By identifying the specific areas in need of improvement, organizations can then begin the difficult task of developing solutions/interventions that will address the specified problems and reduce the likelihood that a similar accident will occur.

Unfortunately, creating, implementing, and ensuring quality interventions succeed still poses a significant challenge for organizations. Scholars have long shown that generating novel and creative ideas can be challenging for numerous reasons: lack of time (Ocasio, 1997), fear of change and failure (Argyris, 1993), lack of attention from the organization (Stalk & Hout, 1990), risk avoidance (Mueller & Thomas, 2001), and many more. Moreover, even when ideas are created and deemed suitable, they are not always adopted and integrated into the organization (Fichman, 2000). Typically, companies and systems attempt to solve the identified problems by applying one or a few of the following "traditional" solutions: adding more training, creating new policies/procedures, or in some cases reprimanding and removing the "problem" personnel. This leads us to wonder if the known issue/problem is solved or if the implemented solutions are just temporary band-aids.

In an attempt to step away from using the same "traditional" solutions, researchers have developed over 70 different idea generation techniques (IGTs) that can help users generate *creative* ideas (Higgins, 2005). One IGT that has continued to gather attention since its inception is brainstorming. Osborn, the founder, and CEO of the advertising giant BBDO (Batten, Barton, Durstine & Osborn), created this technique to help companies and corporations increase creativity (Al-Samarraie & Hurmuzan, 2018). He defined brainstorming as "a creative conference for the sole purpose of producing a checklist of ideas" (Osbon, 1957, pp. 151-152). More specifically, brainstorming refers to the process in which members work together and share ideas to generate as many solutions as possible.

The brainstorming process is made up of two stages that relate to the divergent-convergent continuum (Kalargiros & Manning, 2015). The first stage is focused on generating as many ideas as possible without criticism (divergent thinking). In contrast, the second stage is focused on discussing the developed interventions, with the ultimate goal of combining, improving upon, and deciding on the best or most appropriate solution (convergent thinking). Osborn based the group brainstorming process on four rules: criticism is ruled out, freewheeling is welcome, quantity is wanted, and combination/improvement is sought out and accomplished (Osborn, 1957). Evidence suggests that since its inception, IGT brainstorming has been and continues to be used consistently by organizations to generate interventions (Al-Samarraie & Hurmuzan, 2018; Lehrer, 2012).

In reviewing the extended reach of brainstorming in organizations, Lehrer (2012) noted that brainstorming and its many variations have become "the" process for idea generation. As a result of its growing popularity, researchers began to pursue this line of research to not only replicate Osborn's claim of superior idea quantity and quality but to reach a better understanding of the brainstorming process. Research into brainstorming expanded from just utilizing the traditional face-to-face (F2F) brainstorming approach (described above) to investigating the effect that different modalities (i.e., F2F, electronic brainstorming (EBS), and nominal brainstorming (NBS)) has on idea generation quantity and quality (Al-Samarraie & Hurmuzan, 2018).

In contrast to Osborn's original claim, previous research began to indicate that the brainstorming performance of the traditional brainstorming groups may be inferior to the performance of nominal brainstorming groups in the number of ideas (quantity) generated during a single brainstorming session (Dunnette, Campbell, & Jaastad, 1963; Lamm & Trommsdorf, 1973; Rotter & Portugal, 1969; Taylor, Berry, & Block, 1958). These results were unexpected and ended up separating researchers into two factions. The first group focused their energy on developing a new technique (known as NBS) since it was believed that Osborn's technique was not the best approach to generate interventions (Isaksen & Gaulin, 2005; Rossiter & Lilien, 1994). The second group did not dismiss Osborn's claims as quickly. Instead, they argued that group interaction is different from individual thought processes and is plagued by barriers in communication that individuals do not experience. Therefore, it was believed that group ideation should not be directly compared to the efforts of individuals but instead to other brainstorming groups (i.e., EBS; Diehl & Strobe, 1987).

Both techniques (NBS and EBS) were originally devised and created to overcome some of the negative social influences discovered to affect ideation creation during the F2F brainstorming sessions (e.g., social loafing, production blocking, and evaluation apprehension) (Zhou et al., 2019). The main difference during NBS sessions is that group members generate ideas individually. Those interventions are combined to make a *group* idea generation list (Henningsen and Henningsen, 2013). This line of research gave rise to one alternative IGT known as brainwriting (VanGundy, 1984). Alternatively, EBS utilizes online resources and tools such as email, browser-based systems (i.e., Teams© and Zoom©), chat, and discussion forums to support the group idea generation process. Instead of being physically face-to-face to generate ideas, this process allows distributed teams to collaborate and create ideas simultaneously. Wainfan and Davis (2004) categorized EBS into three subcategories: Videoconference (VC), Audio/teleconference (AC), and computer-mediated communication (CMC). In VC, participants use desktop programs like Teams© or Zoom© to help facilitate idea generation within the group. More specifically, participants in real-time can virtually see and remotely work with one another. Common graphics are shared and can be viewed simultaneously during the meeting. This is in stark contrast to the participants utilizing AC. Participants in the AC subcategory still communicate in real-time but use audio services to communicate (i.e., telephone or conference call). Voice communication is utilized, but no useful real-time video images of the other participants are provided. Finally, CMC is typically text-based and is comprised of either synchronous (i.e., via chat or messaging) or asynchronous (i.e., e-mail, discussion boards) discussion.

Unfortunately, we do not know the specific idea generation technique/s and the modalities WDW utilized to develop their final interventions. What is known is that after WDW analyzed the incident summarized above, they generated and applied the following interventions:

1. Warning signs were increased and revised around the bodies of water found throughout the property to highlight the dangers of being near the water. More specifically, the sign verbiage was updated from "*No swimming*" to "*Danger—alligators and snakes in the area. Stay away from the water. Do not feed the wildlife.*" In addition to the verbiage change, warning signs were updated to include an image of both an alligator and snake.
2. Both rope fences and rock barriers were installed to provide a natural barrier that keeps humans and dangerous wildlife (like alligators) away from each other.
3. WDW expanded upon and provided training that prepared employees to better recognize, report, and interact with wildlife.
4. Finally, WDW has continued working with the Florida Wildlife Commission to remove alligators over four feet that are considered dangerous and threaten their guests.

Although the solutions WDW created look good on paper, are they the *best,* most creative solutions to ensure this event will never occur again? How did they decide upon the final interventions? What ideas were created but not chosen to be utilized?

To date, there is a lack of research regarding a unified process of systematically developing and ranking/choosing interventions. One system safety tool that may accomplish this goal is the **H**uman **F**actors **I**ntervention **M**atrix, also known as HFIX (Shappell & Wiegmann, 2006). This structured brainstorming framework was created as an extension of HFACS (Wiegmann & Shappell, 2003). By using the HFACS framework to analyze accidents, researchers can identify areas in need of improvement and then begin to develop interventions (using HFIX) to address those issues. This process utilizes subject matter experts (SMEs) and ensures that the factors affecting performance are addressed at various levels from multiple directions. Individuals/groups that use the HFIX framework are forced to think outside of the box (i.e., thinking beyond their training and the traditional "typical" solutions usually employed). The HFIX framework takes the identified causal factors (i.e., the unsafe acts level of HFACS) and pits them against five intervention approaches or dimensions: 1. Environmental Factors, 2. Task Factors, 3. Technological Factors, 4. Individual/Team Factors, and 5. Supervisory/Organizational-Centered Factors to develop prospective solutions. Groups utilizing HFIX are reminded not to worry about the idea's cost, feasibility, or effectiveness when generating the interventions.

Consider the opening scene that focused on the little boy who lost his life due to an alligator attack and Disney's final implemented interventions in relation to the five HFIX dimensions introduced above. For example, the Environmental Factors dimension of HFIX focuses on aspects of the physical work environment that can be changed to improve performance. Disney's solutions (i.e., the rope fence and the rock barriers) altered the physical environment to reduce the likelihood that humans and dangerous wildlife (specifically alligators) would get close enough for an attack. Another possible intervention idea could be to drain the lakes so that alligators cannot hide in the depths of the water.

The next dimension is task factors. Task factors refer to the physical and cognitive activities that the individuals or teams complete. Here, researchers are interested in what aspects of the task can be restructured or changed to increase performance and reduce errors. As described above, Disney employees are expected to multitask and complete their job while looking for dangerous animal sightings. While Disney did not release a specific intervention related to this approach, a possible solution that focuses on changing the task would be to hire an operator or team member whose sole job is looking for wildlife that could threaten guests. Once identified, WDW could work with the Florida Wildlife Commission (FWC) to remove alligators over four feet that are considered dangerous and threaten their guests.

The third dimension is technological factors. Technological factors refer to the tools and technology individuals and teams use to complete their work. This dimension focuses on how checklists, equipment, or technology can be redesigned, optimized, or automated to increase performance. For example, one of the many possible interventions that could be created to mitigate and reduce “meetings” between guests and alligators would be to implement an alarm system that goes off (i.e., flashing lights and audible instructions) when wildlife or humans cross the manufactured barrier meant to separate them. Another possible solution could be to deploy a drone that scans, recognizes, and shocks alligators that pass a specific boundary. All ideas created are welcomed at this stage of the game (no matter how crazy they are or may seem to be).

The fourth dimension is individual/team factors. These factors refer to the characteristics (e.g., selection, training, motivation, etc.) of the individuals/teams performing the task. WDW expanded upon and provided training that prepared employees to better recognize, report, and interact with wildlife. One step further could be to incentivize the task at hand. Maybe Disney could offer a bonus to task members who spot and report dangerous wildlife before an event occurs.

The final dimension is supervisory/organizational-centered factors. Supervisory/Organizational-Centered factors refer to the management and oversight of the individuals and teams by those in authority positions within an organization. This dimension focuses on implementing and encouraging safe practices from the supervisory and organizational levels of the company. A possible intervention for this approach could focus on how the organization can better promote and encourage safe practices regarding dangerous wildlife.

Once a multitude of possible solutions and interventions (like the ones above) have been proposed, Shappell and Weigmann (2006) recommend ranking the interventions based on **F**easibility, **A**cceptability, **C**ost, **E**ffectiveness, and **S**ustainability (also known as FACES) to find the best solution. Subject matter experts (SMEs) will rank and score all of the created interventions on a 5-point Likert scale (where 1 indicates “low” and 5 indicates “high”) for each of the dimensions of FACES. Those scores are added to give a final “total” FACES ranking. This process provides researchers with a systematic way to rank the interventions. The interventions with higher FACES scores are considered better than the interventions with lower scores (Shappell & Weigmann, 2006)

Today, HFIX has successfully identified problems and generated a myriad of solutions in multiple industries but has not yet been a primary focus for researchers. Can HFIX and FACES be the solution to getting away from the fixation on the “traditional” solutions when compared to brainstorming?

Significance of Study

To date, there is a dearth of research regarding a unified process of systematically developing and ranking/choosing interventions within the system. This dissertation aims to utilize and validate the Human Factors Intervention Matrix, and the companion assessment tool FACES regarding developing and ranking novel interventions. This goal will be accomplished in two parts. Part one is interested in uncovering whether or not brainstorming with HFIX will generate a higher quantity, a better quality, and a wider breadth of ideas than traditional brainstorming. Part two is focused on whether the modality in which HFIX is used (i.e., F2F, videoconferencing, or teleconferencing) affects the quantity, quality, and breadth of ideas generated.

Chapter Two: Review of Related Literature

Introduction

Chapter two will introduce you to a comprehensive review of the literature pertaining to creative idea generation and selection.

Idea Generation creation

Since the beginning of time, humans have been using divergent thinking and forms of creativity to generate ideas that could solve the myriad of issues/problems they experienced in the world around them. Many researchers consider the success and evolution of the human race to be an account of creativity (Puccio, 2017). Creative solutions were used to solve problems relating to 1. Survival skills (e.g., how best to survive a specific terrain; how to build shelters; how and what to hunt, etc.); 2. Communication skills/aids (e.g., cave paintings, before a common language existed to preserve the memory of things that have happened and provide a way to communicate concepts that were difficult to explain to others); and 3. Teamwork skills (e.g., how to work together to hunt, gather, etc.). Interestingly, how we have utilized creativity has and will continue to change as society evolves.

Previous literature focusing on creativity has been studied in a multitude of domains, including but not limited to health (physical and psychological), psychology, education, engineering, and business management (Anderson et al., 2014; Hennessey & Amabile, 2010; Müller & Ulrich, 2013; Runco, 2004; Yasin & Yunus, 2014). Many organizations and businesses alike have embraced the idea of creativity due to the role researchers have found it plays in fostering innovation and entrepreneurship (Hennessey & Amabile, 2010; Runco, 2004).

Today, creativity allows us to fly through space, explore the depths of the ocean, create brilliant pieces of music and art, develop technology, cure illnesses, and plays an essential role in problem-solving and idea generation (Feist & Gorman, 1998; Runco & Nemiro, 1994).

Creativity Defined

Creativity has its roots in the Latin word *creo*, which means to create/make, and is generally referred to as "thinking outside the box" (Ritter & Mostert, 2017). More specifically, this refers to the ability to generate original ideas or problem-solving solutions that are relevant and of value to the problem at hand (Hennessey & Amabile, 2010; Kaufman & Sternberg, 2010; Paulus & Yang, 2000; Sawyer, 2012). Creativity is understood in regards to a dual-process theory (i.e., thought diverges from two extremes, with the distinction typically being made between convergent and divergent thinking; (Evans & Frankish, 2012; Gabora, 2018, 2019; Sloman, 1996). Convergent thinking (used during the evaluation process) is defined as evaluating and selecting an accurate solution based on constraints, assumptions, and pros/cons analyses. Divergent thinking (used during the intervention creation/idea generation step), on the other hand, is typically defined as the process of generating multiple solutions for a given problem (Gabora, 2018; Piffer, 2012). Divergent thinking occurs spontaneously in a free-flowing manner where many creative ideas are created and then evaluated (using convergent thinking; (Gabora, 2018, 2019).

Guilford (1967), one of the leading American proponents of factor analysis in personality assessment, first proposed the idea of "divergent thinking" being related to creativity in his Model of the Structure of Intellect. This 150-factor Model of the Structure of Intellect is comprised of operations, contents, and products (Guilford & Hoepfner, 1971). The mental operation dimension (i.e., general intellectual processes) is composed of six categories: cognition (knowing), memory recording, memory retention, *divergent production (generation of logical alternatives)*, convergent production (generation of logic-type conclusions), and evaluation. The Content dimension (i.e., the area of information in which the operations are performed/perceived) is comprised of five categories visual, auditory, symbolic, semantic, and behavioral. Finally, the Product dimension (i.e., results that occur once a mental operation is applied to specific content) includes the following six categories: units, classes, relations, systems, transformations, and implications. According to Guilford's Model of the Structure of Intellect, the different intellectual abilities can be organized along these three dimensions. Thanks to Guilford's work, creativity became almost synonymous with divergent thinking and "the measurable components of divergent thinking: fluency (total number of ideas generated), flexibility (number of categories or domains explored), and originality (novelty and rarity of responses) became accepted empirical observables of divergent thinking" (Kalargiros & Manning, 2015).

Previous studies have claimed that the brainstorming session's process can affect an individual's ability to produce creative solutions (Drapeau, 2014; Michinov et al., 2015; Schlee & Harich, 2014). A person's creative ability during the idea generation session is measured according to quality and quantity. Quality refers to how good this idea is in solving the problem based on a set of predetermined criteria, while quantity is how many novel concepts were created during the session (Al-Samarraie & Hurmuzan, 2018). A positive correlation has been reported between the quantity and quality of the brainstorming groups (Adanez, 2005; Diehl & Strobe, 1987, 1991). As the number of ideas created increases, the quality of the ideas theoretically also increases.

Over time, as the understanding of divergent thinking evolved, researchers questioned and revised the idea that creativity ability alone is a synonym of divergent thinking (i.e., fluency, flexibility, and originality). They later added that divergent thinking, alongside other factors, such as personality traits, interpersonal trust, mood/perceptions of the task, and cognitive characteristics (intelligence), are better predictors of creative engagement and performance (Kaufman, 2016; Runco et al., 2010; Sellaro et al., 2014).

Popular Idea Generation Techniques

Due to growing competition worldwide and the increasing change of pace in working environments, there is an evolving understanding that creativity is critical to an organization's innovation capability and long-term success. This is because creativity can be utilized in problem construction, idea evaluation, and idea generation (Wang, 2019). In fact, when facing problems or challenges, many organizations rely heavily upon idea generation techniques (IGTs) to develop creative solutions and interventions. To address the increasing need, researchers have developed various methods to generate innovative ideas, to the extent that they have created over 70 IGTs currently available in the literature today (Higgins, 2005). As a result, people have options when trying to generate novel and creative interventions.

To try and make sense of the IGT options at their disposal, researchers have attempted to categorize the IGTs into specific groups (Higgins, 2005; MacCrimmon & Wagner, 1994; Smith, 1998). For example, Higgins (2005) classified 70 IGTs into two groups: individual and group techniques. Knoll and Horton (2011), on the other hand, described the features of the IGTs (like the cognitive characteristics) but did not provide a system that people could use to help decide which technique one should use. Researchers have also tried to categorize IGTs based on whether they are structured or unstructured. Structured brainstorming IGTs according to Wang (2020), "can be either free association techniques or forced relationship techniques." Unstructured brainstorming IGTs, on the other hand, allow the participants to generate interventions however they see fit with no rules or requirements. Previous research on structured and unstructured techniques suggests that structured/semi-structured brainstorming approaches can help participants generate more interventions (Nijstad, Stroebe, and Lodewijkx, 2002). Wang (2020) argues that the distinction between structured and unstructured techniques seems less useful than other distinguishing factors of IGTs because most, if not all, IGT techniques are structured. It was not until Wang (2019) that a comprehensive and systematic theory-based classification system was proposed.

Wang (2019) proposed a taxonomy that classified 87 idea generation techniques. The 87 identified IGTs were first sorted into two categories: individual techniques and group techniques. The individual techniques category includes methods designed to support individual creative work and is categorized by 1.) Whether or not it introduces external stimuli (i.e., checklist); and 2.) Whether or not the technique emphasizes explicit or implicit processing of knowledge (i.e., knowledge you consciously work to remember vs. information that is effortless to remember).

On the other hand, the group techniques category is comprised of techniques developed explicitly for group usage. Wang (2019) broke down and categorized the group techniques by 1. Whether or not it introduces external stimuli (i.e., checklist, etc.); and 2. Whether people generate and share ideas verbally or silently. For the purposes of this dissertation, we will be focusing in detail on the four group techniques, more specifically the verbal techniques that the author Wang created and described based on the literature (Wang 2019).

While not of interest for this dissertation, the first two groups describe a means by which silent techniques can be classified. The first IGT category defined by Wang was silent techniques with external stimuli. This collection consists of IGTs that depend on the idea generation process being silent. This is typically accomplished by IGTs being generated via writing or drawing. Silent techniques with internal stimuli categorize the second group. This category is comprised of IGTs whose idea generation process is silent, and no external stimuli is needed. An example of this technique is Nominal brainstorming. Participants are given a problem and generate ideas individually before reviewing and deciding on the best intervention.

The following two groups describe the classification system Wang (2019) proposed for group techniques. The third group, also identified as verbal techniques with external stimuli, classifies IGTs based on the verbal expression of ideas between group members and includes external stimuli (i.e., a checklist). A prime example is brainstorming with a checklist or cognitive aid. Group members can work together, discuss, and generate ideas. To help the groups generate ideas, a checklist of thoughtprovoking questions or pictures could be utilized to continue the flow of ideas being generated. Finally, the last group contains IGTs that generate ideas verbally with internal stimuli (i.e., memory). An example of this technique would be traditional brainstorming. Group members utilizing traditional brainstorming work together to discuss and generate interventions. The taxonomy described above helps researchers make sense of the current IGTs in the literature. It is important to note that some techniques, like brainstorming, could fit into multiple categories depending on the type of stimuli used (as shown above).

As well as creating a taxonomy, Wang (2019) developed a guide for IGT selection informed by empirical studies. Previous research reveals that brainstorming and brainwriting are among the most studied techniques (Wang, 2019). With brainstorming and its many variations being considered “the” process for idea generation (Lehrer, 2012). This guide is a good starting point for recognizing what type of IGTs should be utilized based on the specific goals of the task. To use the comprehensive guide for IGT selection, the first question that must be asked is whether or not the interested party wants to generate ideas individually or in a group setting.

While not necessarily in the scope of this dissertation, if the user is planning on generating ideas individually, then two questions will help to inform which technique should be utilized. The first idea generation situation that should be considered is whether the individual wants to analyze the creative task and generate ideas in an organized manner (if so, then explicit processing should be used) or if they would rather search randomly and use inspiration (if so, then implicit processing should be used). The last idea generation situation that should be considered is whether or not the need to break mental fixation is high or low. If the need to develop new perspectives is high, then external stimuli should be utilized. On the other hand, if the need to break fixation is low, internal stimuli should be used. The answers to these questions then offer the user the type of IGT that should be utilized.

Of interest for this dissertation is what IGT should be utilized when the users are planning on generating interventions as a group. Wang (2019) has proposed four idea generation situations to consider when deciding the best IGT to use for the task. The first question focuses on the size of the idea generation groups. If the group is going to be large, then silent techniques are suggested. If the group size is going to be small, then either silent or verbal techniques are considered appropriate. The following idea generation situation proposed is whether random variation or creative synthesis is required or coveted.

Random variation results from group members' diverse backgrounds, perspectives, and imaginations (if coveted silent techniques are recommended; Chen & Adamson, 2015). Alternatively, creative synthesis integrates group member perspectives so that everyone has the opportunity to discuss, understand, and even build upon each of the generated ideas (if deemed necessary, then verbal techniques are recommended). The following idea generation situation that groups should take into account, according to Wang (2019), is whether or not the group members are introverted or extroverted. If the majority of members within a group are introverted, it is suggested to utilize a silent technique. However, if most of the group members are extroverted, then either silent or verbal techniques can be used. Finally, as with the individual idea generation questions, the last question is focused on whether the group needs to develop new perspectives. If so, then utilizing external stimuli is recommended. If not, then internal stimuli should be used. This dissertation aims to generate interventions for a proposed problem utilizing small groups of three. To help groups develop new perspectives, they will be given a checklist with probing questions designed to assist in the idea generation process. Our requirements suggest that utilizing a verbal technique with external stimuli is appropriate.

This dissertation will focus specifically on the verbal group technique, brainstorming.

Brainstorming

There are multiple accepted ways to generate innovative ideas. The first of which is brainstorming. Brainstorming is arguably one of the most popular techniques used today to foster group creativity and has grown to be almost synonymous with idea generation (Al-Samarraie & Hurmuzan, 2018; Shih, Venolia, & Olson, 2011). Contrary to decision-making techniques that aim to eliminate unsuitable ideas to reach a final consensus, the brainstorming process focuses on gathering as many ideas as possible. In 1957, Osborn introduced group brainstorming in corporate settings to help increase the level of creativity. He based the brainstorming technique on four rules that groups are to follow during the brainstorming session. 1. Criticism is ruled out. 2. Freewheeling is welcome (the wilder, the better). 3. Quantity is wanted. 4. Combination and improvement are sought out and accomplished (See Appendix H).

Osborn sold his method and touted that groups using his process would generate the highest number of ideas and, in turn, the most quality (or "best") ideas. This process spread and quickly became the favored method for generating ideas in organizations (Jablin, Sorensen, & Seibold, 1978; Lehrer, 2012; Taylor, Berry, & Block, 1958). As brainstorming became popular, researchers set out to validate and test Osborn's claim. Taylor and colleagues (1958) conducted the first of several investigations focused on replicating and answering whether or not brainstorming facilitates or inhibits creative thinking. To explore the connection between creative thinking and traditional brainstorming, ninety-six male participants were equally divided into either the brainstorming condition (experimental condition) or the nominal brainstorming group (control condition). In addition, each participant was randomly assigned to a group of four within their respective condition. Findings of this research line indicated that traditional brainstorming groups' performance was inferior to the performance of nominal brainstorming groups in the number of ideas generated (Taylor, Berry, & Block, 1958). These unexpected results ended up separating researchers into two factions. The first group focused their energy on developing a new technique (known as NBS) since it was believed that Osborn's technique was not the best approach to generate interventions (Isaksen & Gaulin, 2005; Rossiter & Lilien, 1994). The second group did not dismiss Osborn's claims as quickly. Instead, they argued that group interaction is different from individual thought processes and is plagued by barriers in communication that individuals do not experience. Therefore it was believed that group ideation should not be directly compared to the efforts of individuals but instead to other brainstorming groups (i.e., EBS; Diehl & Strobe, 1987).

Groups participating in brainstorming frequently contain people of unequal or dissimilar statuses and backgrounds. These groups may include any combination of employees, managers, engineers, marketers, clients, agency personnel, and anyone that could be affected by the solutions created. The unequal status and backgrounds of the individuals could pose problems during the idea generation session due to possible deference to those perceived to be of higher rank or due to a social desirability bias (Fisher, 1993). Social desirability bias is an innate bias introduced in an individual's answers that allows a person to portray him or herself in the best, most socially desirable manner (Rotter, 1971). To try and mitigate the biases mentioned above, researchers remind people during the brainstorming session that organizational rank should be ignored and all generated ideas should be given equal status and thought. Unfortunately, even with that reminder, it can be challenging for people to get over the initial bias.

In the literature today, there are three main ways or mediums that brainstorming techniques can be utilized and delivered to groups: verbal/traditional brainstorming (TBS), nominal brainstorming (NBS), and electronic brainstorming (EBS).

Traditional brainstorming refers to the type of brainstorming where group members dynamically participate in dialogue and interact with one another by verbally sharing ideas one at a time. This technique has been shown to help stimulate ideas. It stays true to Osborn's rules when producing brainstorming (i.e., rule out criticism, no freewheeling, quantity is encouraged, and combining ideas). In the literature, traditional brainstorming has been found to increase the number of ideas generated in a classroom setting (Parnes & Meadows, 1959), improve students' writing more than nominal brainstorming (Rao, 2007; Shengming, 2008), as well as increase students satisfaction and perception of the brainstorming task (Comadena, 1984; Rietzschel et al., 2006a, 2006b). In contrast, previous research has also found that traditional brainstorming has the potential to produce fewer ideas depending on the context (Miller, 2009; Putman & Putman, 2009), can be less effective than nominal brainstorming (Lewis et al., 1975), can produce a limited amount of creative ideas (Feinberg & Nemeth, 2008), and can be less effective at creating innovative or practical solutions in a timely manner (Sparrey, 2020). While Ritter & Mostert (2018) found no significant differences in creativity or number of intervention ideas between traditional brainstorming and nominal brainstorming.

When utilizing traditional brainstorming, there are social factors that can affect idea generation. An unfortunate byproduct of using traditional brainstorming to generate interventions is that "group think" and peer pressure can affect whether or not an individual in the group speaks up for fear that if they do, they will be ridiculed. Diehl and Strobe (1987, 1991) have demonstrated that apprehension regarding sharing one's ideas in the group, anonymity, and production blocking can affect the level of motivation in the individuals within the group. Interestingly, these effects can affect the group and lead to the group underperforming, even though the participants within the group tend to think that they did relatively well in the session (Paulus et al., 1993).

Finally, although traditional brainstorming sessions have been reported to be an exceptional tool for stimulating students' comprehension, scheduling and maintaining active participation are two challenges that may be difficult to overcome. Typically this is where students or group members lose focus and become lost during the discussion. This eventually can lead to the participants feeling disorganized and less motivated to join back in and participate (Mohammad & Hussein, 2013).

The conflicting results do not necessarily mean that traditional brainstorming isn't effective. Instead, it may mean that the effect traditional brainstorming has on idea generation is dependent on the setting/organization in which it is completed, the individuals' knowledge of the subject matter, and the nature of the imposed creativity task. This was explained earlier in the description of the overall guide for IGT selection created by Wang (2019).

The next form of idea generation is the nominal brainstorming technique (NBS). Participants that utilize this technique generate creative ideas individually without communicating with the other group members (Henningsen & Henningsen, 2013). NBS was initially created to overcome some of the negative social influences that were discovered to affect ideation creation during the traditional (f2f) brainstorming sessions (e.g., social loafing, production blocking, and evaluation apprehension; Zhou et al., 2019). Previous research has illustrated that in certain settings, participants who work alone generate more ideas than they do working in groups (Paulus et al., 1995, 1996; Pinsonneault et al., 1999).

Several studies reported an increase in the quantity, quality, and overall performance of the individuals who participated in the nominal brainstorming technique (McGlynn et al., 2004; Rietzchel et al., 2006a, 2006b). In fact, Kerr & Murthy (2004) found that overall the nominal brainstorming technique was at least as good, if not better, than the idea's generated by the electronic brainstorming group. One downside to using nominal brainstorming to collect and assess ideas is that working alone takes longer and prevents participants from actively engaging and building upon group ideas (Boddy, 2012; Shih, Venolia, & Olson, 2011).

Within the literature, nominal brainstorming has mixed research results. While there are studies that show the positive effect of nominal brainstorming on idea generation (as shown above), there are studies that did not have an effect. For example, Kramer and his colleagues (1997) found that nominal and face-to-face brainstorming groups selected ideas of comparable quality. Initially, they provided Osborn's (1953) brainstorming instruction to nominal and face-to-face groups, which then brainstormed for 10 minutes. These groups then selected their best idea. Afterward, the quality of each idea was assessed via a four-item measure of feasibility, effectiveness, creativity, and interest. As expected, nominal groups generated more ideas than F2F or traditional brainstorming groups. Despite these differences in idea quantity, however, the selected ideas were similar in quality. This brings up an interesting point related to the generated ideas: Does quantity matter as much if the final intervention quality is comparable?

The final brainstorming technique is electronic brainstorming. In today's times, working in distributed teams is becoming more and more commonplace. Electronic video collaboration tools such as Microsoft Teams© or Zoom©, alongside tools such as email, chat, and discussion forums, are used to help facilitate and provide a space where groups can communicate with their teams and make creative decisions (Baruah & Paulus, 2016).

MIS researchers introduced electronic brainstorming (EBS) as a way for dispersed group members to facilitate idea generation simultaneously without some of the problems inherent to traditional brainstorming (i.e., production blocking and evaluation apprehension). EBS appears to be a useful technique for generating ideas in groups and has garnered some serious attention over the past few years. It involves groups of various sizes generating ideas about a specific topic simultaneously (i.e., Nunamaker et al., 1991; Valacich et al., 1994) or, less often, at different times (i.e., Michinov & Primois, 2005; de Vreede, Briggs, & Reiter-Palmon, 2010). In most studies, participants are in the same room and type their ideas on a computer keyboard while also having the ability to discuss the responses that they have created. This allows the generated idea to be visualized and re-read several times (e.g., chat function in teams) on the computer screen. Wainfan and Davis (2004) categorized EBS into three subcategories: Videoconference (VC), Audio/teleconference (AC), and Computer-mediated communication (CMC).

Videoconferencing (VC) allows participants to use computer programs like Teams© or Zoom© to help facilitate idea generation within the group. Participants can, in real-time, see and remotely work with one another. This medium allows graphics and text to be shared and viewed simultaneously during the meeting. Audio/teleconferencing (AC) is similar to videoconferencing but removes all visual cues from the other group members. This reduces individuals' ability to visually show agreement or understanding, predict when an opening to speak will be available, express attitudes through posture and facial expressions, and provide crucial nonverbal communication (Isaacs & Tang, 1994). In fact, Burgoon et al. (2003) found that lying may be easier to detect (when people are paying attention) in AC than in F2F communication because there are theoretically fewer visual distractions. Young's (1974) research indicated that participants report lower confidence in AC brainstorming than in f2f brainstorming. When comparing status among individuals in the AC brainstorming condition, DeSanctis found that in new groups, the emergence of leaders is inhibited, but in established groups, the results are mixed and tend to show the emergence of a hierarchy (Harmon 1995). Finally, while not in scope with the purpose of this dissertation, CMC is typically text-based and is comprised of either synchronous (i.e., via chat or messaging) or asynchronous (i.e., e-mail, discussion boards) discussion. Participants do not vocally speak to one another. They instead share ideas via chat/typing.

Regarding EBS, one of the most significant advantages is that it reduces or eliminates the detrimental blocking effects of verbal brainstorming (e.g., Diehl & Stroebe, 1987; Gallupe et al., 1994). This is because no one in the group must wait for their turn to speak since they can, without interrupting another, type their response for the group to see (i.e., Gallupe et al., 1994; Paulus et al., 2002). This positive effect has been found to increase with larger groups (this is directly opposite of what happens with large f2f groups). In fact, previous research has discovered that large groups whose members share ideas through computers outperform both equivalent nominal groups whose members do not share their ideas and groups whose members share their ideas verbally (e.g., Dennis & Valacich, 1993; Dennis & Williams, 2005; DeRosa et al., 2007). In addition, the current literature has found that EBS: outperforms traditional and nominal brainstorming in quality and quantity of ideas generated (Dennis & Valacich, 1993, 1994; Valacich et al., 1994; Ziegler et al., 2000), promotes students' satisfaction (Aiken et al., 1996), fosters group synergy and stimulation (Dennis, Hayes, & Daniels, 1999), and overall productivity (Roy et al., 1996). Contrary to the positive results mentioned above, researchers have found that in certain settings, similar to traditional and nominal brainstorming, electronic brainstorming generated fewer combinations (Kohn et al., 2011) and was not found to produce an increase in quality (Paulus, Dugish, Dzindolet, Coskun, & Putman, 2002). These results lead us to wonder if the modality in which brainstorming is utilized affects idea quantity and quality.

Brainwriting

The next lesser-used, accepted form of idea generation is known as brainwriting. Compared to the oral sharing of ideas in groups during brainstorming, brainwriting involves a group of people silently writing and sharing their written ideas (VanGundy, 1983). Brainwriting was developed based on the principles of NBS. This process is helpful when conflicts/tensions among participants are expected to occur or when dominant people are present in the brainstorming session. Research has revealed that brainwriting can yield superior idea generation compared to either non-sharing or nominal groups (Gryskiewic, 1981; Paulus & Yang, 2000; Thompson, 2003). In contrast to traditional brainstorming, brainwriting (initially designed for the marketing industry) could potentially minimize the effect of status differentials, dysfunctional interpersonal conflicts, domination by one or two group members, and the pressure to conform to group norms (VanGundy, 1983; 1984). This process might also eliminate production blocking, reduce social loafing, and encourage careful processing of shared ideas (Paulus & Yang, 2000). Interestingly, while specific brainwriting techniques can be effective, brainstorming is popular and utilized more in the literature. The literature has outlined six types of brainwriting, which are provided below. They are known as 1. The original brainwriting, 2. The collective notebook, 3. The brainwriting pool, 4. Pin cards, 5. Battelle- bildmappen-brainwriting, and the 6. SIL method. The first three methods are considered to be pure brainwriting techniques since they do not involve discussing the ideas written down during the generation method.

The first method is known as 6-3-5 Brainwriting. Rohrbach created this version of brainwriting in 1968. 6-3-5 Brainwriting consists of six participants, supervised by a moderator, who are given a problem and asked to write down three ideas on their paper in five-minute intervals. Once completed, participants pass the paper to the right and complete the exercise again (for a total of five times). When the paper returns to the original owner, the group could conceivably have 108 unique ideas to work with in thirty minutes. This type of brainwriting has a following within education, specifically to improve students' writing skills (Halifah, 2019).

The second type of brainwriting is called the collective notebook (CNB). John Haefele of Procter and Gamble (1962) created this procedure to help collect ideas from a relatively large number of individuals throughout an organization. In contrast to the nominal group technique, people using this method are not in the same physical setting when generating ideas. This process involves the individuals selecting a notebook that includes a problem statement and the collective notebook instructions. They are then instructed to write down at least one new idea every day for a month. Next, the participant selects the "best" ideas from their list and sends them to the project coordinator. From there, the project coordinator reviews, organizes, and develops a final summary that the participants can review and discuss (Heslin, 2009; Vangundy, 2007).

The third method is known as the brainwriting pool technique. This technique was initially developed at the Battelle Institute and involves sharing ideas between group members (Heslin, 2009; VanGundy, 2007). This method involves the leader reading a problem statement to a group of five to seven people. The participants then write down four ideas on a sheet of paper and exchange it for another member's sheet. They then use the other member's ideas for inspiration and list additional ideas. This is repeated for about 20 to 30 minutes.

The fourth method is known as pin cards. This method is a simple alternative to brainstorming that is useful whenever a skilled leader is unavailable, group members are inexperienced, and are not trained in brainstorming. The basic steps include five to eight people, each with a stack of large index cards and writing utensils. One idea is silently written on each card and then passed to the right. The person reading the new cards then tries to go off the written idea with either a new idea or a way to modify it. The cards are then passed to the right, and the process continues for about twenty to thirty minutes. The cards are then taken and literally "pinned" to a bulletin board or spread out on a large table. Another round of writing ensues, only this time it is based on any new ideas that spawn in their mind from the cards already created (Heslin, 2009; VanGundy, 1987).

The fifth type of brainwriting is Battelle-bildmappen-brainwriting (BBB) (Warfield, Geschka, & Hamilton, 1975). The Battelle-bildmappen-brainwriting technique begins similarly to classical brainstorming but is followed by idea stimulation from a picture collection. This technique ends with another round of idea generation using the traditional brainstorming technique described above. There was no literature experimentally testing this type of brainwriting.

The sixth and final type of brainwriting is known as the SIL method. This method was developed in the late 1970s by Helmut Schlicksupp and allows each member to propose an idea sequentially. The ideas are then gradually combined into one solution (Moon, & Han, 2016). The SIL method is a combination of individual work and teamwork. Each person brings their own unique knowledge and expertise to the table (Gaubinger, Rabl, Swan, & Werani, 2015). They each design a solution that is as detailed as possible, then present their ideas, which are then discussed to find the strengths and weaknesses. Finally, a combined solution is built from all of the ideas' strengths. Compared to brainstorming, this procedure is much more challenging for both the moderator and the participants, and the time invested is more along the two to three-hour range. However, the trade-off is that each participant has participated and feels successful once the final product is created.

Introduction to HFIX

The Human Factors Intervention Matrix (HFIX), created by Shappell & Wiegmann in 2006, is a system based on human factor engineering principles that allow organizations to develop and implement targeted interventions to reduce error in the system. The Human Factors Intervention Matrix was created as an addition to the Human Factors Analysis and Classification System framework (HFACS; Wiegmann & Shappell, 2003). The Human Factors Analysis and Classification System (HFACS) helps identify the underlying human factors issues that contribute to accidents in a myriad of complex systems. Using this framework to analyze accidents, researchers can identify regions needing improvement and then begin to develop targeted interventions to address those identified problems. On top of providing a system that can identify weaknesses/areas within systems, Shappell and Wiegmann (2006) also created and provided a comprehensive systematic methodology for identifying prospective interventions and ensuring that the most expansive assortment of interventions is considered to address the areas being targeted. This model is similar to the original Haddon Matrix method. The original model Haddon (1972) created investigates the host, agent, and environmental factors before, during, and after the accident. Likewise, the HFIX framework and methodology ensure that factors affecting human performance are addressed from multiple directions and levels, thus promoting the creation of effective targeted interventions.

In order to develop and implement targeted interventions, the HFIX methodology utilizes subject matter experts (SMEs). SMEs include but are not limited to the individuals on the front line and administration. SMEs consist of anyone who has "skin in the game." During the HFIX session, SMEs are put together and told to brainstorm intervention strategies to address the causal issues discovered by the HFACS methodology. The SMEs are encouraged to "think outside the box" and are advised to use probes to generate ideas to address each problem. The SMEs are also reminded that once they have exhausted all possibilities for a given approach, they can move on to the next one. They are told not to worry about the hows (i.e., cost, feasibility, or effectiveness). This is because, according to Haddon (as cited in Runyan, 1998) and (Hennessey, 1989), "intervention feasibility," while necessary, should not be a consideration until all other elements have been figured out. He believed that if feasibility were considered too early, that creativity would be stifled, and ideas that could have been created would now not be thought of or discarded (Grebler et al., 2014)

Similarly to the Haddon Matrix, the HFIX framework puts the identified threats from the HFACS analysis against (not three but) five intervention approaches. These five intervention approaches help to capture the underlying contributing factors of human error and give researchers a way to address the root causes of the errors and inefficiencies in the system (Shappell & Wiegmann, 2006). The dimensions consist of 1. Environmental factors, 2. Task factors, 3. Technological factors, 4. Individual/Team factors, and 5. Supervisory/Organizational-Centered factors. While not done intentionally, each of the five HFIX intervention approaches fits in nicely with specific components of the established HFACS framework (stated by Scott Shappell, 2020). Furthermore, each dimension tackles the selected problem from a different direction, which helps ensure that the participants generate the widest variety of targeted interventions within the brainstorming session (See Appendix C).

The first intervention approach: Environmental factors refer to the physical work environment in which the personnel/front line employees perform their job/activity. This dimension aligns within the physical environment category of HFACS and consists of information regarding the working environment. Working environment refers to the atmosphere, ground, and weather, as well as everything that is comprised within the ambient environment that could affect and, in turn, improve performance. Examples include vibrations, temperature, and lighting. The SMEs are given specialized questions that focus on the lighting, the noise level, the amount of clutter, etc., to help guide the brainstorming session for that category (See Appendix C).

The second intervention approach: Task factors refer to the physical and cognitive work activities performed by individuals and teams. At this level of HFIX, researchers are interested in what aspects of the task can be restructured or changed to increase performance and reduce the number of errors occurring. The SMEs are asked questions based upon the unsafe supervision tier (which has four causal categories: inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations) of HFACS. This tier focuses on decisions at the supervisory level that can affect an individual's performance and the overall safety and efficiency of a system. Probing/priming questions were developed to help the SMEs while they brainstorm interventions on this approach (See Appendix C).

The third intervention approach: Technological factors refer to the tools and technology individuals and teams use to complete their work. This dimension fits in nicely with the technological environment tier of HFACS. SMEs generating interventions in the technological factors dimension of HFIX are asked to focus on how the checklists, equipment, or technology can be redesigned, optimized, or automated to increase performance. To see probes that were created to assist the SMEs during idea generation, see Appendix C.

The fourth intervention approach: Individual/Team factors, refers to the characteristics of the individuals and teams performing the task. More specifically, this approach is focused on how the human can be changed to affect performance and reduce errors. This can be done through selection, training, motivation, etc. A checklist containing probing questions was created to help SMEs generate interventions within this approach (See Appendix C).

The fifth and final intervention approach: Organizational-Centered factors, refers to the management and oversight of the individuals and teams by those in authority positions within an organization. This approach aligns with the organizational influences tier of HFACS and asks the SME to consider ways the organization can affect change. Probes were created to help SMEs generate interventions regarding this approach (See Appendix C).

Intervention Ranking/Selection

Once the idea generation portion of a brainstorming session has finished, there are numerous created interventions to wade through and choose from. The next step is figuring out what to do with the generated ideas. Currently, there is no gold standard in the literature regarding selecting the "final" best intervention/s. In fact, in an "ideal" traditional brainstorming group, one would expect the participants to take the ideas they have generated and then discuss all available alternatives before considering and deciding upon the final solution. Unfortunately, that is not typically the case (Stasser, 1999). Johnson and D'Lauro (2018) conducted two experiments interested in *when* the groups' selected best idea was generated in the brainstorming session. In their first study, thirty-six participants were randomly assigned to twelve three-person groups. Each group was told to work together to brainstorm ideas on various topics. After the brainstorming session, the groups were sent the ideas generated in either the order they were created (control) or randomized (experimental group) and asked to select the best idea. They found that groups generally tended to choose ideas created early in the brainstorming session as their best idea, regardless of the order in which the ideas were presented. The authors provided a possible explanation for this result, stating that ideas generated at the beginning of the session were less original than later ideas. The groups may have selected the ideas generated toward the beginning of the session because their understanding of a good idea was heavily influenced by how feasible it was rather than how original it was.

In their second study, Johnson and D'Lauro (2018) investigated how the definition of "best" contributes to the selection of interventions in groups. To test this hypothesis, forty-five participants were assigned to three-person groups and asked to complete a fifteen-minute brainstorming session. Contrary to study one, participants were asked to select two ideas: 1. the most feasible and 2. the most original. According to previous research, the participants should have selected early ideas when focusing on feasibility and later ideas when focusing on originality (Baruah & Paulus, 2016; Kohn & Smith, 2011; Osborn, 1957). However, Johnson and D'lauro did not see that with their participants and postulated that it is possible participants were hesitant to select highly original ideas. This phenomenon has been seen in multiple studies within the literature. For example, participants reported being less satisfied when Rietzschel et al. (2010) instructed participants to select the most creative ideas rather than the best ideas. Rietzschel et al. (2010) believed this occurred because the participants preferred to choose practical ideas. This means that not all of the ideas are being thoroughly reviewed. So how do you decide what to do with all of the recommendations that were created so that they all get a fair shot at being the intervention that is picked? Is there a tool that could be utilized to take the guesswork out of ranking interventions?

Introduction to FACES

Fortunately, the HFIX process works hand in hand with an intervention ranking system created by Shappell and Wiegmann (2006), called FACES. FACES is an acronym for an intervention ranking system that stands for 1. Feasibility, 2. Acceptability, 3. Cost, 4. Effectiveness, and 5. Sustainability. Feasibility refers to whether or not the change can be employed easily and quickly (i.e., can it be done?). Acceptability refers to whether or not the frontline personnel will readily accept the change (i.e., will operators accept it?). Cost refers to whether or not the benefit outweighs the cost (i.e., can we afford it?). Effectiveness refers to how well the intervention will solve the problem (i.e., will it work?). Finally, sustainability refers to how well the intervention will last over time (i.e., will it last?).

Once participants have completed the brainstorming intervention idea portion through HFIX, subject matter experts (SMEs) are directed to use FACES to rank all created interventions. SMEs are asked to rate each intervention on a 5-point Likert scale, where 1 indicates "low" and 5 indicates "high." The FACES rankings for each causal category are then added to give a total score, which is then used to help determine which interventions should be selected for implementation (Shappell & Wiegmann, 2006). The final product allows researchers to visualize threats identified by the HFACS analysis against the intervention approaches created by HFIX and the evaluation criteria FACES (See Figure 1). Applying this HFIX framework to map specific interventions onto a matrix can provide a broader perspective and enable a more structured approach to intervention development (Shappell & Wiegmann, 2006).

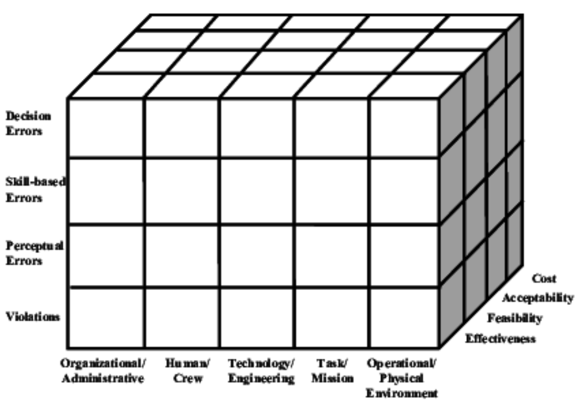

Figure 1. Example of HFIX Cube ($HFIX^3$) (Shappell & Weigmann, 2006)

Chapter Three
Methodology

Introduction

This section provides a comprehensive account of the methodology used for this study. This includes information regarding the participants, sample size, data collection process, instruments used, and the chosen research design/statistical procedures used for data analysis.

Research Design and Rationale

A quantitative approach with a true experimental study design was utilized. More specifically, a 2x2 between-subjects experimental design, combined with parametric and nonparametric analyses, helped to uncover the relationship that the independent variables (Brainstorming Condition: HFIX vs. Traditional; and Modality: Face to Face- F2F and Videoconferencing- VC) had with the dependent variables (idea quantity, idea quality, and breadth of ideas). Parametric analyses (e.g., MANOVAs) and nonparametric analyses (Chi-squares) were utilized.

Research Questions

1. RQ1: Will brainstorming using HFIX generate a higher quantity of ideas compared to traditional brainstorming?
2. RQ2: Will brainstorming using HFIX generate higher quality ideas than traditional brainstorming?
3. RQ3: Will brainstorming using HFIX generate a higher number of ideas in each of the HFIX categories when compared to traditional brainstorming?
4. RQ4: Does the modality (F2F or VC) in which HFIX is used affect the quantity of ideas created?
5. RQ5: Does the modality (F2F or VC) in which HFIX is used affect the quality of ideas created?
6. RQ6: Does the modality (F2F or VC) in which HFIX is used affect the number of ideas generated in each HFIX category?

Research Hypotheses

Hypothesis 1

H_{01}: There will be no difference in the quantity of ideas when comparing brainstorming with HFIX to traditional brainstorming.

$H_{A1:}$ Brainstorming with HFIX will generate a higher quantity of ideas than traditional brainstorming.

Hypothesis 2

H_{02}: There will be no difference in the quality of the ideas when comparing brainstorming with HFIX to traditional brainstorming.

$H_{A2:}$ Brainstorming with HFIX will generate higher quality ideas than traditional brainstorming.

Hypothesis 3

H_{03}: There will be no difference in the number of ideas generated within each of the categories of HFIX when comparing brainstorming with HFIX to traditional brainstorming.

$H_{A3:}$ There will be a difference in the number of ideas generated within each of the categories of HFIX when comparing brainstorming with HFIX to traditional brainstorming.

Hypothesis 4

H_{04}: There will be no difference in the quantity of ideas created when comparing the modality in which HFIX is utilized (F2F and VC).

H_{A4}: Brainstorming with HFIX via VC will generate a higher quantity of ideas than brainstorming with HFIX F2F.

Hypothesis 5

H_{05}: There will be no difference in the quality of the ideas created when comparing the modality in which HFIX is utilized (F2F and VC).

H_{A5}: Brainstorming with HFIX via VC will generate a higher quality of ideas than brainstorming with HFIX F2F.

Hypothesis 6

H_{06}: There will be no difference in the number of ideas generated within each of the categories of HFIX when comparing the modality in which HFIX is used (F2F and VC).

H_{A6}: There will be a difference in the number of ideas generated within each of the categories of HFIX when comparing the modality in which HFIX is used (F2F and VC).

Participants

One hundred twenty participants were recruited from the Embry-Riddle Aeronautical University (ERAU) student population in Daytona Beach, Florida. They were required to be at least 18 years old and were solicited using the research and participant management system called SONA Systems®.

Sample Size and Group Assignment

This study explored whether the brainstorming type (HFIX or Traditional) and the modality used (F2F or VC) affected the overall quantity, quality, and number of ideas created in each of the HFIX categories. As illustrated in Figure 2, one hundred and twenty participants were assigned to forty groups of three. Each group of three participants was then randomly assigned to one of the four conditions: Traditional brainstorming via F2F, Brainstorming with HFIX via F2F, Traditional brainstorming via VC, and Brainstorming with HFIX via VC (meaning that there would be ten groups of three participants per condition).

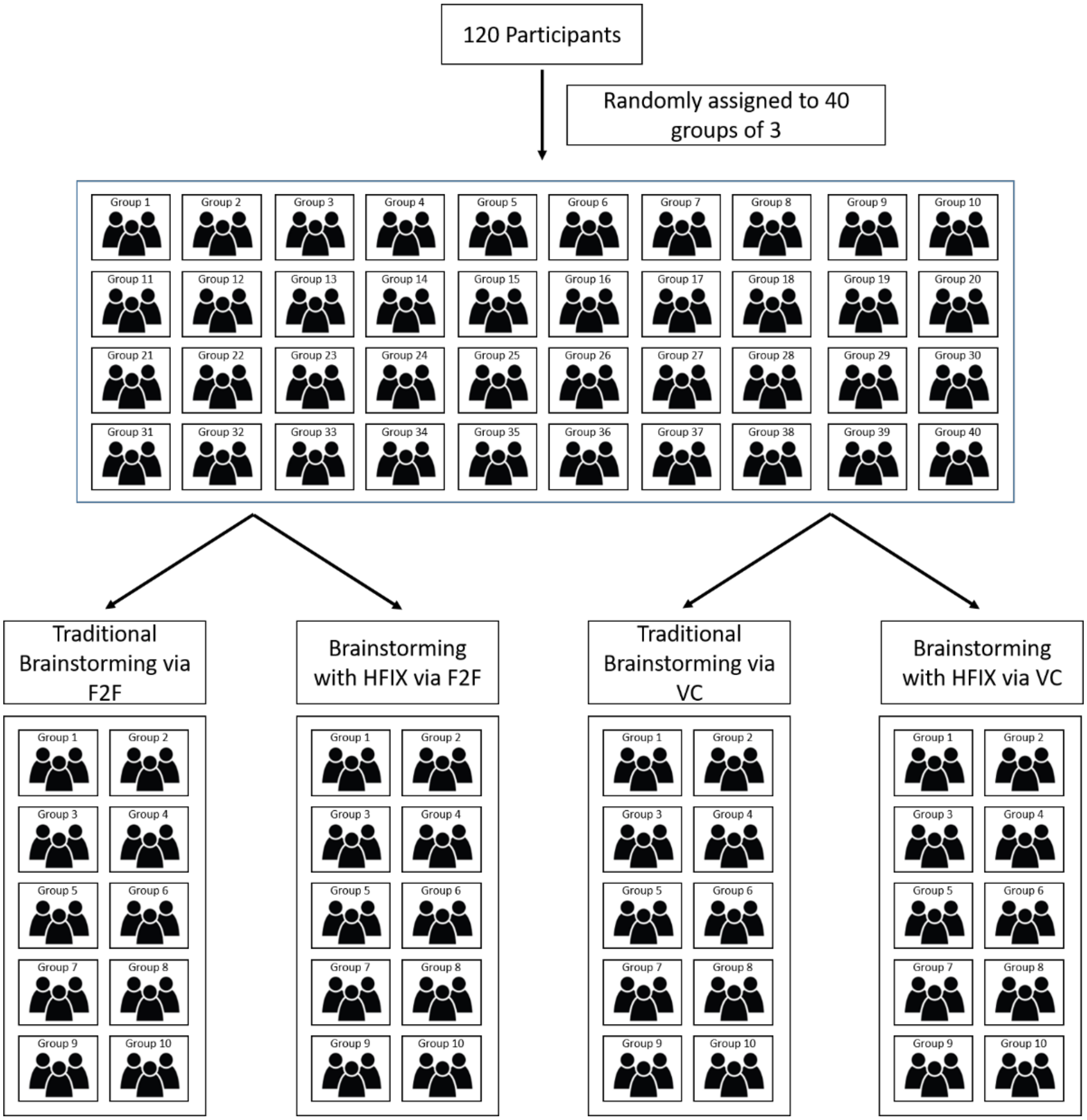

Figure 2. Participants and Group Assignment

Materials

Demographic survey

The demographics survey consists of five questions relating to the background of the participants (See Appendix B). These questions aim to understand the participants within the study better. This particular form asks for information regarding their age, gender, ethnicity, academic standing, and major.

HFIX

Shappell and Weigmann created the Human Factors Intervention Matrix (HFIX) in 2006 as an addition to the Human Factors Analysis and Classification System (HFACS) framework (Wiegmann & Shappell, 2003). HFIX is based on human factor engineering principles that allow organizations to create and implement targeted interventions. Its ultimate goal is to reduce errors within the system. HFIX provides a systematic methodology for identifying prospective interventions and ensuring that the most expansive assortment of interventions is considered to address the targeted areas.

The HFIX methodology utilizes SMEs to brainstorm intervention strategies across five intervention approaches or dimensions to develop interventions. The first dimension is Environmental Factors, which refer to the physical work environment (e.g., ground, weather, temperature, lighting, etc.) in which personnel and frontline employees perform their job. How can we change the environment to improve performance? The second dimension is task factors. Task factors refer to the physical and cognitive activities that the individuals or teams complete. Here, researchers are interested in what aspects of the task can be restructured or changed to increase performance and reduce errors. The third dimension is technological factors. Technological factors refer to the tools and technology individuals and teams use to complete their work. More specifically, this dimension is interested in how checklists, equipment, or technology can be redesigned, optimized, or in some cases, automated to increase performance. The fourth dimension is individual/team factors. These factors refer to the characteristics (e.g., selection, training, motivation, etc.) of the individuals/teams performing the task. The final dimension is organizational-centered factors. Organizational-Centered factors refer to the management and oversight of the individuals and teams by those in authority positions within an organization.

Participants were given checklists containing prompts/questions for each of the dimensions of HFIX (See Appendix C). This was to help the participants generate ideas for each intervention approach. To date, this is the first study that has looked to utilize and validate HFIX in developing novel interventions.

FACES

Shappell and Wiegmann (2006) developed an intervention ranking system called FACES (See Appendix E). FACES is an acronym that stands for:

- **F**easibility (i.e., can it be done?),
- **A**cceptability (i.e., will operators accept it?),
- **C**ost (i.e., can we afford it?),
- **E**ffectiveness (i.e., will it work?), and
- **S**ustainability (i.e., will it last?).

Once the interventions were generated, three subject matter experts (SMEs) rated each intervention on a 5-point Likert scale, where 1 indicates a "low" score and 5 indicates a "high" score for each of the FACES categories. The individual SME FACES rankings for each causal category were then added to give a total score, which was then used to help determine which interventions should be selected for implementation (Shappell & Wiegmann, 2006).

Microsoft Teams©

Microsoft Teams© is a collaborative workspace within Microsoft 365/Office 365 that allows teams (regardless of their location) to have office conversations and meetings, video chats, phone calls, and document sharing all in one place. With teams worldwide moving faster than ever to remote work, it has become as important as ever to understand the effect that the modality has on productivity and idea generation. Therefore, Microsoft Teams© was utilized for the VC conditions.

Procedure

Part 1: Idea Generation

Before arrival, participants were assigned to groups of three within one of the four conditions: Traditional brainstorming via F2F, Brainstorming with HFIX via F2F, Traditional brainstorming via VC, and Brainstorming with HFIX via VC.

Traditional Brainstorming via F2F

Upon arrival, participants were asked to read and sign an informed consent (See Appendix A). Next, participants were given a brief demographic survey that gathered information regarding their age, gender, ethnicity, academic standing, and major (See Appendix B). After completing the Demographic survey, the traditional brainstorming group via F2F was shown a video and given reference sheets explaining Osborn's four rules of brainstorming: 1. No criticism, 2. Freewheeling is welcome (the wilder, the better), 3. Quantity is wanted, and 4. Combination and improvement should be sought out and accomplished (See Appendix H). The Traditional Brainstorming via F2F group was then presented the following brainstorming problem: *"One of the biggest problems we have in the world today is getting people (especially children) to wash their hands regularly, despite the scientific link between washing hands and killing germs. In your group, brainstorm ways to get children to wash their hands after going to the bathroom."* After the problem had been described to the group, the participants were asked if they had any questions. If the group did not have any questions, the researcher (i.e., the scribe) started the fifty-minute timer and told the group they could begin.

The interventions produced during the brainstorming session were combined with the other interventions created by the groups in the Traditional Brainstorming via F2F condition. Since groups generated similar or identical interventions to one another, the combined list of interventions was thoroughly reviewed and sorted by two independent raters. The results from those raters were then compared, and any intervention that was duplicated or found to be similar to another intervention was combined, leaving only one item to represent each idea in the intervention pool for later ranking and analysis. This process is shown in Figure 3, where groups one, two, and three generated similar responses relating to gamifying the task. Therefore, the following three responses regarding gamifying the task were combined to create one "final" intervention used during the idea ranking stage.

"*Brainstorm ways to get children to wash their hands after going to the bathroom*"						
Groups:	Group 1	Group 2	Group 3	Group 4	Group 5	Combined "Final" intervention for ranking
Example Intervention:	*"Make washing their hands a game."*	*"Gamify washing their hands"*	*"Use a video game the children can play while washing their hands."*	-----------	----------	*"Make washing their hands a game using something like a video game."*

Figure 3. Example of the combination process for duplicate/similar interventions created in the same condition

As illustrated in Figure 4, each group within the brainstorming with HFIX via F2F condition was given the brainstorming problem and asked to generate interventions for fifty minutes. Those interventions were then compiled to produce the total number of ideas generated per group. Then each group list was combined to generate the total number of interventions created per condition. Next, duplicates/similar interventions within the condition were combined (leaving only one representation per idea), and a final list remained that represented the total number of unique interventions generated within the condition. For example, if each group developed 50 interventions, each condition would yield an overall total of 500 interventions (50 interventions x 10 groups). Once duplicates were removed from the 500 created interventions, it was anticipated that about 150-200 novel interventions would be available for analysis per condition.

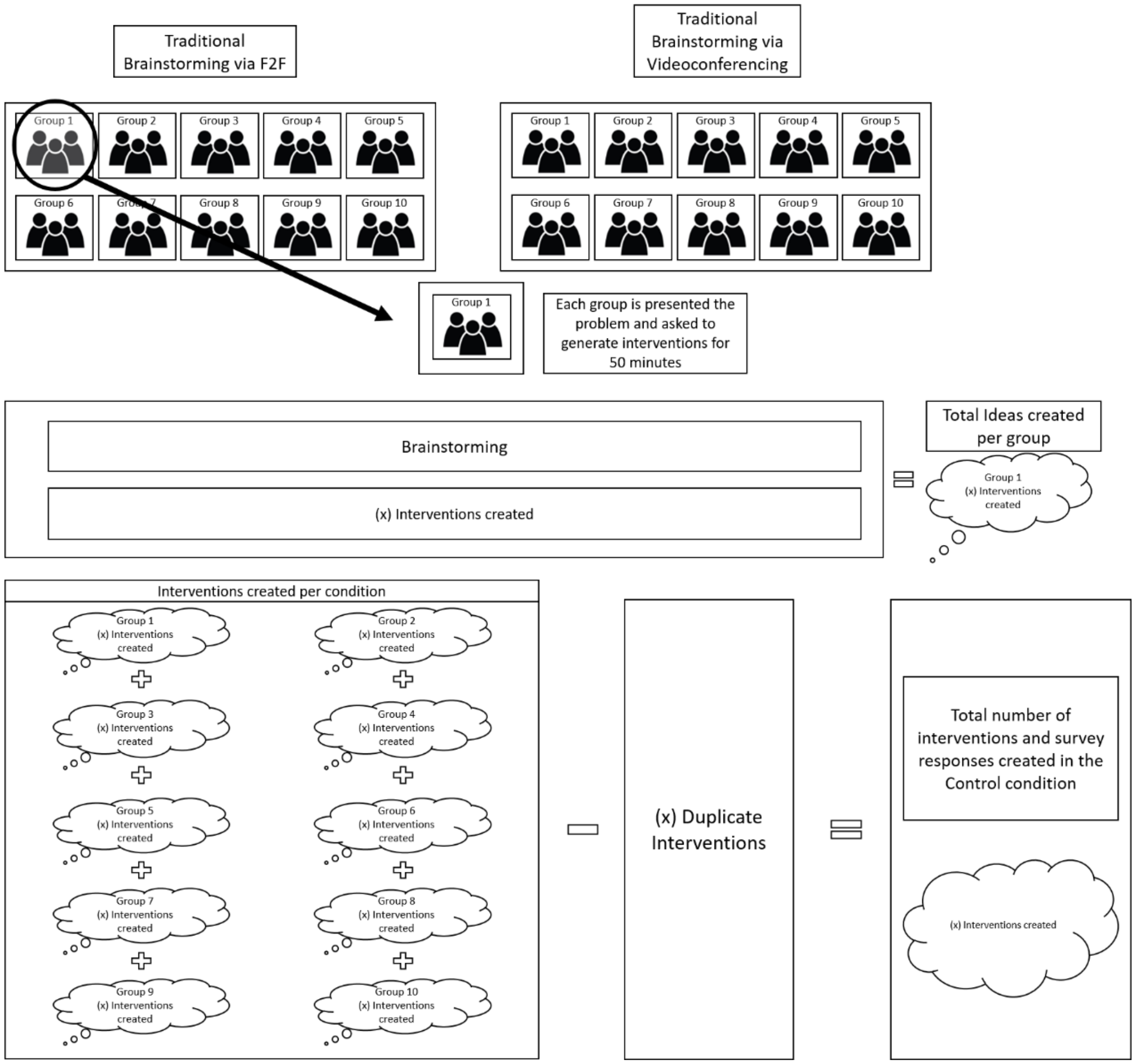

Figure 4. Total number of interventions and survey responses created in both the Traditional Brainstorming F2F and VC conditions

Brainstorming with HFIX via F2F

Upon arrival, participants were asked to read and sign an informed consent (See Appendix A). Next, participants were given a brief demographic survey that gathered information regarding their age, gender, ethnicity, academic standing, and major (See Appendix B). After completing the Demographic survey, the Brainstorming with HFIX via F2F group was asked to watch a video (5-10minutes; See Appendix G for transcript) introducing HFIX and the five intervention approaches. Once the video finished, participants in this condition were given reference sheets for each of the five approaches of

HFIX that they could reference at any time (created by Shappell and Weigmann; See Appendix C). The HFIX group was then given a reference sheet outlining Osborn's four rules of brainstorming: 1. No criticism, 2. Freewheeling is welcome (the wilder, the better), 3. Quantity is wanted, and 4. Combination and improvement should be sought out and accomplished (See Appendix H).

As shown in Figure 5, the groups in the HFIX condition were presented with the brainstorming problem (See Appendix F), told that the researcher would be the scribe, and were asked to create interventions for all five of the HFIX categories. The participants were then given 10 minutes per HFIX category to generate interventions for 50 minutes. If the participants did not have any questions, the researcher (i.e., the scribe) started the timer and had them begin. Every 10 minutes, the researcher would direct the participants to start generating ideas for the next HFIX category. In order to address the similar or identical interventions developed between groups in this condition, the combined list of interventions was thoroughly reviewed and sorted by two independent raters. The results from those raters were then compared, and any intervention that was duplicated or found to be similar to another intervention was combined, leaving only one item to represent each idea in the intervention pool for later ranking and analysis. This process is shown in Figure 3.

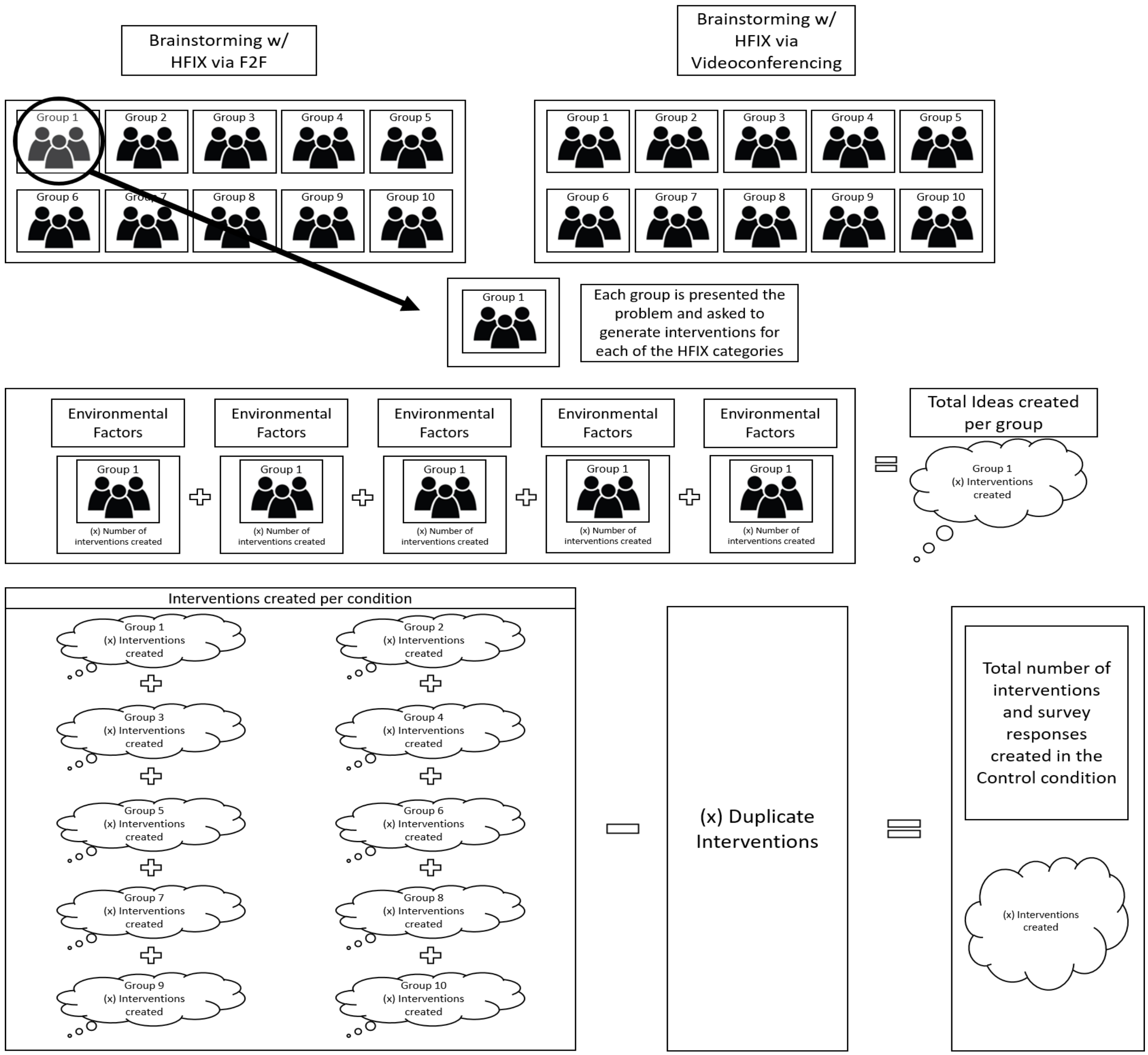

Figure 5. Total number of interventions created in both the HFIX F2F and VC conditions

Traditional Brainstorming via VC

Before the study began, participants were emailed the link to the Microsoft Teams© meeting, along with brief instructions regarding how to use Microsoft Teams©. Once the participants joined the Microsoft Teams© meeting, the researcher quickly went through the different components of Microsoft Teams© that the participants had at their disposal during the study and asked them to turn on their video. Participants were then sent a Google Forms link containing the study's informed consent in the Microsoft Teams© chat. They were then asked to read and sign if they agreed to participate in the study (See Appendix A). Next, participants were asked to complete a brief demographic survey that gathered information regarding their age, gender, academic standing, and ethnicity (See Appendix B). The videoconferencing group was then shown a video and given reference sheets explaining Osborn's four rules of brainstorming: 1. No criticism, 2. Freewheeling is welcome (the wilder, the better), 3. Quantity is wanted, and 4. Combination and improvement should be sought out and accomplished (See Appendix H). The Traditional Brainstorming via VC group were then presented the following brainstorming problem: *"One of the biggest problems we have in the world today is getting people (especially children) to wash their hands regularly, despite the scientific link between washing hands and killing germs. In your group, brainstorm ways to get children to wash their hands after going to the bathroom."* After the problem had been described to the group, the participants were asked if they had any questions. If the group did not have any questions, the researcher (i.e., the scribe) started the fifty-minute timer and told the group they could begin.

Similar to the Traditional Brainstorming F2F group, interventions produced during the brainstorming session were combined with the other interventions created by the groups in the Traditional Brainstorming via VC condition. Since groups generated similar or identical interventions to one another, the combined list of interventions was thoroughly reviewed. During that review process, any intervention found to be duplicated or similar to another intervention was combined, and only one item was left for later ranking and analysis (See Figure 3).

Brainstorming with HFIX via VC

First, participants were emailed the link to the Microsoft Teams© meeting, along with brief instructions regarding how to use Microsoft Teams©. Once the participants joined the Microsoft Teams© meeting, the researcher quickly went through the different components of Microsoft Teams© that the participants had at their disposal during the study and asked them to turn on their video. Next, a Google Forms link containing the study's informed consent was shared in the Microsoft Teams© chat. Next, participants were asked to read and sign if they agreed to participate in the study (See Appendix A). Next, participants were asked to complete a brief demographic survey that gathered information regarding their age, gender, academic standing, and ethnicity (See Appendix B). The videoconferencing group was then shown a video and given reference sheets explaining Osborn's four rules of brainstorming: 1. No criticism, 2. Freewheeling is welcome (the wilder, the better), 3. Quantity is wanted, and 4. Combination and improvement should be sought out and accomplished (See Appendix H). The Brainstorming with HFIX via VC group was then presented the following brainstorming problem: *"One of the biggest problems we have in the world today is getting people (especially children) to wash their hands regularly, despite the scientific link between washing hands and killing germs. In your group, brainstorm ways to get children to wash their hands after going to the bathroom."* After the problem had been described to the group, the participants were asked if they had any questions. If the group did not have any questions, the researcher (i.e., the scribe) started the fifty-minute timer and told the group they could begin.

Similar to the Brainstorming with HFIX F2F group, interventions produced during the brainstorming session was combined with the other interventions created by the groups in the Traditional Brainstorming via VC condition. Since groups generated similar or identical interventions to one another, the combined list of interventions was thoroughly reviewed. During that review process, any intervention found to be duplicated or similar to another intervention was combined, and only one item was left for later ranking and analysis (See Figure 3).

The Study 1 method described above for each of the four conditions is outlined below in Figure 6.

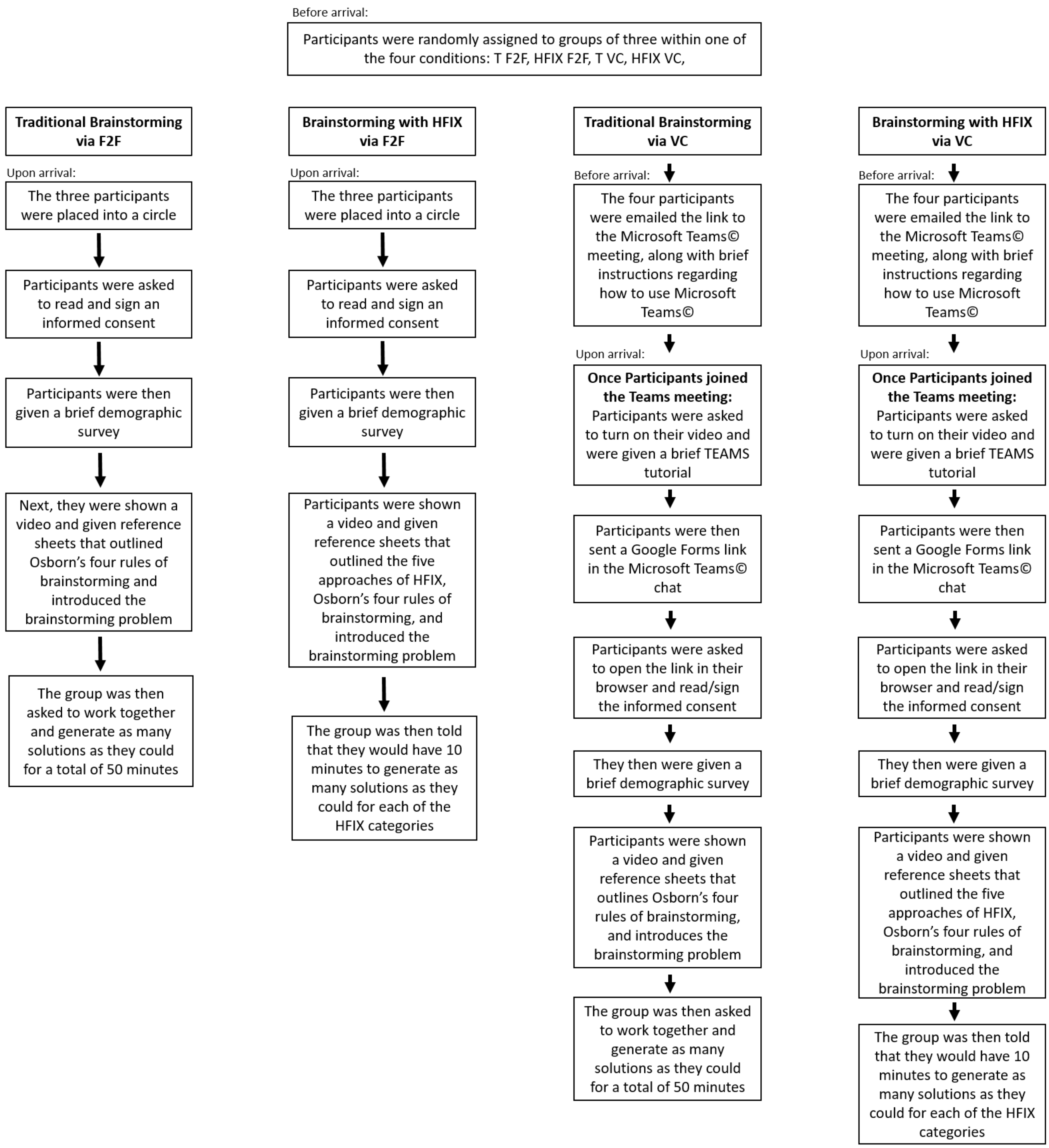

Figure 6. Study 1 Methods

Part 2: Idea ranking utilizing FACES

HFIX and FACES Training

Dr. Scott Shappell, an expert in human factors and co-creator of the HFIX/FACES methodology, trained three undergraduate research assistants. This training included an overall description of HFIX and FACES, an extensive discussion of each dimension of HFIX and FACES, and hands-on exercises that allowed them to practice classifying and then ranking the generated interventions.

HFIX Coding

Before the three raters began coding, the author systematically reviewed the list of ideas generated in each group and removed any duplicate interventions (leaving only one of each idea coded). Figure 4 shows how the combination/removal process of similar and identical ideas was accomplished. In that example, three of the five groups generated an intervention focused on gamifying the task. Since they all refer to the same task, those three interventions would be collapsed into one code for raters to review (as shown in the example).

Finally, the three raters were given the final list of generated ideas and asked to code each into the best fitting HFIX category. Consensus coding was utilized. If a disagreement occurred, the raters were told to discuss it until an agreement was made. If an agreement could not be met, it was determined that the lead researcher would be the tiebreaker. An example of the codebook that each rater utilized when coding the interventions into the appropriate HFIX category is illustrated in Figure 7.

		HFIX Category				
	Intervention	Environmental Factor	Task Factor	Technological Factor	Individual/Team Factor	Organizational-Centered Factor
1	*Example Intervention:* Turn the handwashing task into a game where students can progress through levels based on how well they wash their hands.		X			
2	*Example Intervention:* Shock anyone who leaves the bathroom without washing their hands.			X		
3	…	…	…	…	…	…
…	…	…	…	…	…	…

Figure 7. HFIX Codebook

The individual responses in each HFIX codebook were combined and placed into a Master HFIX codebook.

FACES Ranking

As shown in Figure 8, three different raters were asked to rank each intervention on a 1-5 Likert scale, with 1 indicating "low" and 5 indicating "high" for each of the five dimensions of FACES. The final rater scores for each dimension of FACES were then averaged together, and those scores were then summed to give a "total" FACES score.

For example, item one (*"Example Intervention:* Turn the handwashing task into a game, where the student can progress through levels based on how well they wash their hands*)* received scores from each of the three raters for the following categories: feasibility, acceptability, cost, effectiveness, and sustainability. When focusing on the feasibility of the intervention (i.e., can the intervention be easily implemented), each rater gave the intervention a four. The three scores (total of twelve), when averaged (divided by three), resulted in a final feasibility score of 4. When focusing on acceptability (i.e., will the change be readily accepted), each rater gave the intervention a five, which, when averaged together, gave a final average score of 5. Regarding cost (i.e., does the benefit outweigh the cost), raters one and three gave the intervention a score of two, while rater two gave the intervention a score of one, for a final score of five. That final score was divided by three to provide an average cost score of 1.67. For effectiveness (i.e., how effective will the intervention be at eliminating the problem), raters one and two gave a score of four, while rater three gave a score of five. When these three scores were averaged together, they resulted in an average effectiveness score of 4.33. Finally, for sustainability (i.e., how well will the intervention last over time), all three raters gave a score of three, which, when averaged together, resulted in an average sustainability score of 3. The final average scores for each FACES category were then summed to give a final score of 18 out of 25.

In contrast, item two (*Example Intervention:* Shock anyone who leaves the bathroom without washing their hands) received the following scores from the three raters for each FACES dimension. Regarding feasibility, rater one gave a score of two, and raters two and three gave a score of one, for an average feasibility score of 1.33. For acceptability, each of the three raters gave a score of one. This resulted in an average acceptability score of 1. When factoring in cost, rater one and two gave a score of one, while rater three gave a score of two. This led to an average cost score of 1.33. For effectiveness, raters one and three gave a score of five, while rater two gave a score of four. This resulted in an average effectiveness score of 4.67. Finally, the three raters scored the intervention based on how likely it was to last over time (sustainability). Rater two and three gave a score of three, while rater one gave a score of two, which, when averaged together, resulted in a 2.67 sustainability score. The final average scores for each FACES category were then added together to give a score of 11 out of 25.

When reviewing the scoring results from the three raters utilizing FACES, it is clear from our example that overall, item one (with a total FACES score of 18/25) is a better solution than item two (with a total FACES score of 11/25). The higher the score, the "better" the intervention.

		FACES Dimension										
	Intervention	Feasibility	**Avg.**	Acceptability	**Avg.**	Cost	**Avg.**	Effectiveness	**Avg.**	Sustainability	**Avg.**	**Total FACES score**
1	*Example Intervention:* Turn the handwashing task into a game where students can progress through levels based on how well they wash their hands.	Rater 1: 4 Rater 2: 4 Rater 3: 4	4	Rater 1: 5 Rater 2: 5 Rater 3: 5	5	Rater 1: 2 Rater 2: 1 Rater 3: 2	1.67	Rater 1: 4 Rater 2: 4 Rater 3: 5	4.33	Rater 1: 3 Rater 2: 3 Rater 3: 3	3	**18**
2	*Example Intervention:* Shock anyone who leaves the bathroom without washing their hands.	Rater 1: 2 Rater 2: 1 Rater 3: 1	1.33	Rater 1: 1 Rater 2: 1 Rater 3: 1	1	Rater 1: 1 Rater 2: 1 Rater 3: 2	1.33	Rater 1: 5 Rater 2: 4 Rater 3: 5	4.67	Rater 1: 2 Rater 2: 3 Rater 3: 3	2.67	**11**
3	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…

Figure 8. FACES Codebook

Chapter 4: Results

Introduction

This research aimed to utilize and validate the Human Factors Intervention Matrix and the companion assessment tool FACES for developing and ranking novel interventions. The previous chapter discussed this work's design and the materials and methods utilized in data collection. *Chapter 4* discusses the analyses used in this research, specifically the descriptive statistics, the statistical tests, their associated statistical assumptions, and their results. All data analyses were conducted using Microsoft Excel and IBM Statistical Package for the Social Sciences (SPSS) software.

General Design

The research study used a true experimental study design with both Multivariate analysis of variance (MANOVA) and Chi-square tests for independence as the statistical procedures for data analyses. The independent variables in this study were the brainstorming condition (HFIX vs. Traditional brainstorming) and Modality (F2F vs. VC). The dependent variables were idea quantity, quality, and breadth of ideas. If the analysis was found to be significant, main effects and post hoc analyses were to be assessed. For each of the analyses reported below, assumptions testing was completed, and violations, when they occurred, are noted below.

Analyses

Descriptive Statistics

One hundred and twenty participants (n = 120) were randomly assigned to one of the four conditions (F2F Traditional (n = 30), F2F HFIX (n = 30), VC Traditional (n = 30), VC HFIX (n = 30)). The average age of the participants in this experiment was 21.41 years (SD = 5.50). This sample was made up of 58.33% females (n = 70) and 41.66% males (n = 50). Participants were also asked about their ethnicity, class standing, and major. A breakdown of the descriptive statistics is illustrated in Table 1.

Table 1
Summary of Descriptive Statistics

	Variable	N	M	SD
	Age	120	21.41	5.50
Gender	Male	50 (41.67%)		
	Female	70 (58.33%)		
Ethnicity	Hispanic/Latino	17 (14.17%)		
	White	74 (61.67%)		
	Black/African American	10 (8.33%)		
	Asian/Pacific Islander	12 (10.00%)		
	Other	7 (5.83%)		
Class Standing	Freshman	37 (30.83%)		
	Sophomore	21 (17.50%)		
	Junior	20 (16.67%)		
	Senior	28 (23.33%)		
	Graduate Student	14 (11.67%)		
Major	Engineering & Engineering Technology	14 (11.67%)		
	Business, marketing, or Economics	2 (1.67%)		
	Social Sciences (e.g., Human Factors, Homeland Security, Global Studies, etc.)	41 (34.17%)		
	Science (e.g., Biology, Chemistry, Computer Science, etc.)	30 (25.00%)		
	Humanities (e.g., History, English, Arts, etc.)	1 (0.83%)		
	Aviation (e.g., Air Traffic Control, Unmanned Arial Systems, Flight, etc.)	32 (26.67%)		
	Other	0		

Assumptions of Statistical Tests Used

Assumptions for the chosen statistical analyses (Chi-Square test for independence and MANOVA) are described below (Pallant, 2010).

Chi-Square test for independence assumptions:

Assumption 1. The count data in the cells being measured are considered categorical.

Assumption 2. The levels of the variables are mutually exclusive.

Assumption 3. The sample size was adequate. The number of cases in each cell is more than the minimum required to run the analyses.

MANOVA assumptions:

Assumption 1. The dependent variables (Quality scores for Feasibility, Acceptability, Cost, Effectiveness, and Sustainability) are all analyzed as continuous variables.

Assumption 2. The two independent variables (Brainstorming type and Modality) are categorical, independent groups.

Assumption 3. Different participants were used for each condition.

Assumption 4. The sample size was adequate. The number of cases in each cell is more than the minimum required to run the analyses.

Assumption 5. Boxplots and Mahalanobis Distances found no significant univariate or multivariate outliers in the data set. Therefore, no outliers were removed for analysis.

Assumption 6. The dependent variables (Quality scores for Feasibility, Acceptability, Cost, Effectiveness, and Sustainability) were normally distributed for both independent variables (Brainstorming type and Modality) ($p > 0.05$).

Assumption 7. There is no obvious evidence of non-linearity after reviewing the appropriate scatterplots; therefore, the assumption of linearity was satisfied.

Assumption 8. Box's test of equality of covariance matrices was conducted to assess the homogeneity of variance-covariances matrices. The assumption of homogeneity of variance-covariance was violated ($p = .000$). Pillai’s trace criterion was utilized to address the violation, and a more conservative alpha level was set ($p = .01$).

Assumption 9. A correlation was run between the dependent variables (Feasibility, Acceptability, Cost, Effectiveness, and Sustainability). The dependent variables were found to be slightly correlated with one another ($p < .05$).

Hypothesis Testing

Quantity: Hypothesis 1 and Hypothesis 4

Chi-square tests for Independence were conducted to test H_{01} (there will be no difference in the quantity of ideas when comparing brainstorming with HFIX to traditional brainstorming) and H_{04} (there will be no difference in the number of interventions created when comparing the modality in which HFIX is utilized). As described above, there were no assumption violations (See Chi-square test for independence assumptions).

The first Chi-square test for independence was performed to assess whether there was an association between the number of interventions generated when considering the brainstorming type. A significant difference was discovered between brainstorming with HFIX ($n = 653$) and traditional brainstorming ($n = 534$), $\chi^2(1) = 11.93$, $p < .05$.

A second Chi-square test was utilized to see whether or not the modality in which HFIX is used affected the ideas generated. The results indicated that a significant difference was discovered χ^2 (3) = 22.43, $p < .05$. When reviewing the number of interventions generated, the F2F/H condition ($n = 363$) seems to have developed more interventions than the F2F/T ($n = 252$), VC/T ($n = 282$), and VC/H conditions ($n = 290$).

Quality: Hypothesis 2 and Hypothesis 5

A two-way between subjects MANOVA was performed to test H_{02} (no difference in the quality of the ideas when comparing HFIX to traditional brainstorming) and H_{05} (no difference in the quality of the ideas generated when comparing the modality in which HFIX is used). Five dependent variables were used: Feasibility, Acceptability, Cost, Effectiveness, and Sustainability. The independent variables were brainstorming technique (HFIX, Traditional) and modality (F2F, VC). Preliminary assumption testing was conducted and summarized above (See MANOVA assumptions). The omnibus test showed that there was a statistically significant interaction effect between Modality $F(5, 1179) = 13.72$, $p = 0.00$; Pillai's Trace = 0.06; partial eta squared = .06, Brainstorming type $F(5, 1179) = 18.65$, $p = 0.00$; Pillai's Trace = 0.07; partial eta squared = 0.07, and Modality * Brainstorming type $F(5, 1179) = 10.97$, $p = 0.00$; Pillai's Trace = 0.04; partial eta squared = 0.04. A breakdown of the main effects for Modality, Brainstorming type, and Modality * Brainstorming type is illustrated in Table 2. Variables found to be significant are bolded.

Table 2
Summary of Main Effects

	Variable	Df	F	Sig	Partial Eta Squared
Modality	**Feasibility**	1	64.41	0.01	.052
	Acceptability	1	4.08	0.04	.003
	Cost	1	51.69	0.01	.042
	Effectiveness	1	11.63	0.01	.010
	Sustainability	1	4.302	0.04	.004
Brainstorming type	**Feasibility**	1	9.03	0.01	0.05
	Acceptability	1	25.98	0.01	0.00
	Cost	1	0.39	0.44	0.04
	Effectiveness	1	7.78	0.01	0.01
	Sustainability	1	7.93	0.01	0.00
Modality * Brainstorming Type	**Feasibility**	1	15.26	0.01	0.01
	Acceptability	1	3.54	0.06	0.00
	Cost	1	1.36	0.24	0.00
	Effectiveness	1	0.01	0.94	0.00
	Sustainability	1	10.93	0.01	0.01

As shown in Table 2, the modality utilized significantly affected the Feasibility, Cost, Effectiveness, and Sustainability scores. The MANOVA results showed that participants in the VC conditions, regardless of the brainstorming type utilized, generated slightly more feasible (*M* = 4.06, *SD* = 0.77) and cost-effective interventions (*M* = 3.99, *SD* = 0.79) than in the F2F conditions (See Figure 9 and Figure 10).

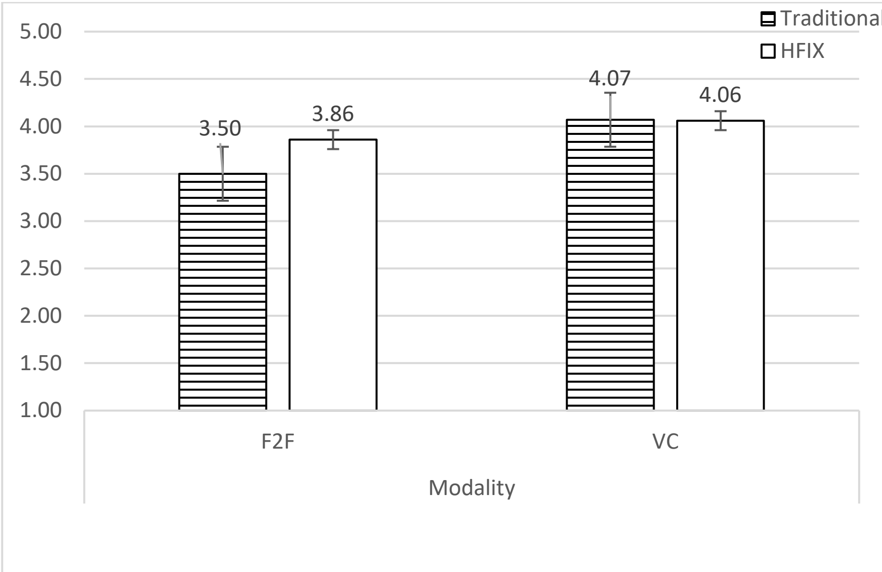

Figure 9. Estimated Marginal Means of Feasibility

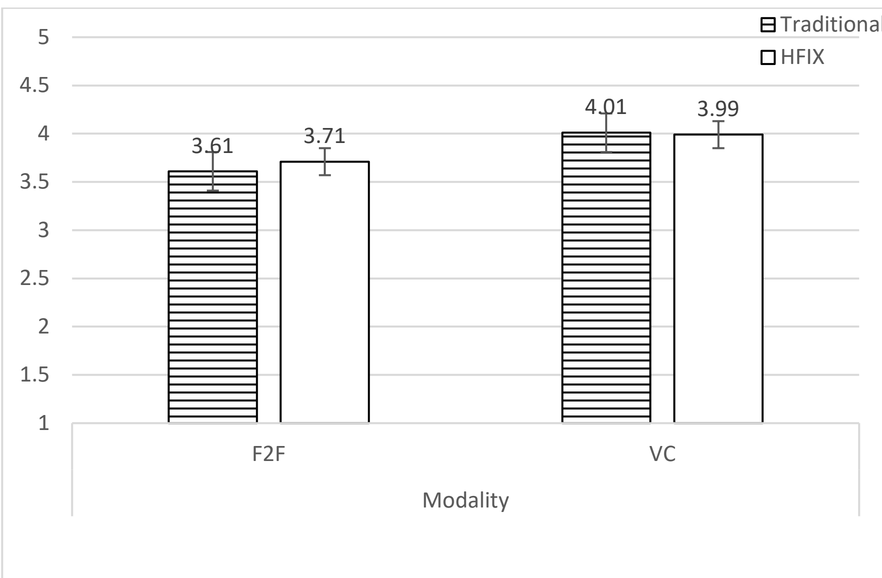

Figure 10. Estimated Marginal Means of Cost

The F2F conditions on the other hand generated interventions that were considered to be slightly more effective ($M = 2.85$, $SD = 0.62$) and sustainable ($M = 3.12$, $SD = 0.57$) than the VC conditions (See Figure 11 and Figure 12).

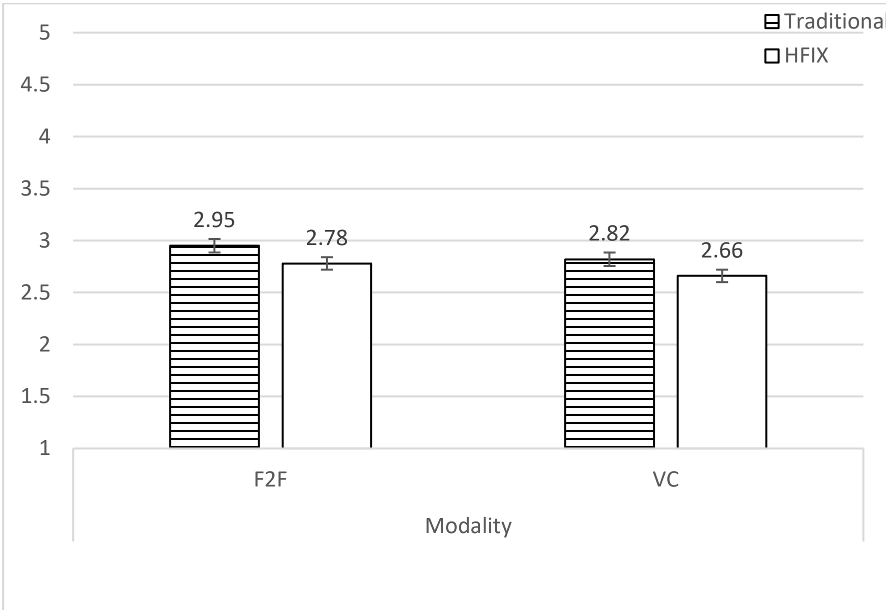

Figure 11. Estimated Marginal Means of Effectiveness

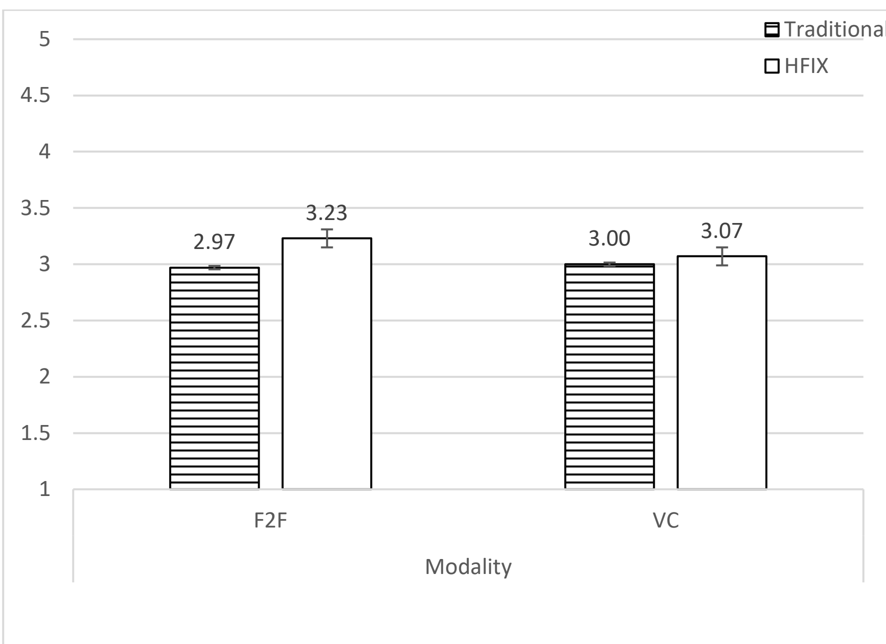

Figure 12. Estimated Marginal Means of Sustainability

Similarly, the brainstorming type showed significant differences in Feasibility, Acceptability, Effectiveness, and Sustainability scores. More specifically, the participants that generated interventions using the HFIX brainstorming technique created more feasible (*M* = 3.95, *SD* = 0.78), acceptable (*M* = 4.07, *SD* = 0.69), and sustainable (*M* = 3.16, *SD* = 0.52) interventions than the participants generating via the traditional brainstorming technique (See Figures 9, 12, 13). Interestingly, the traditional brainstorming condition was found to have generated more effective interventions (*M* = 2.88, *SD* = 0.66) when compared to brainstorming with HFIX (see Figure 11).

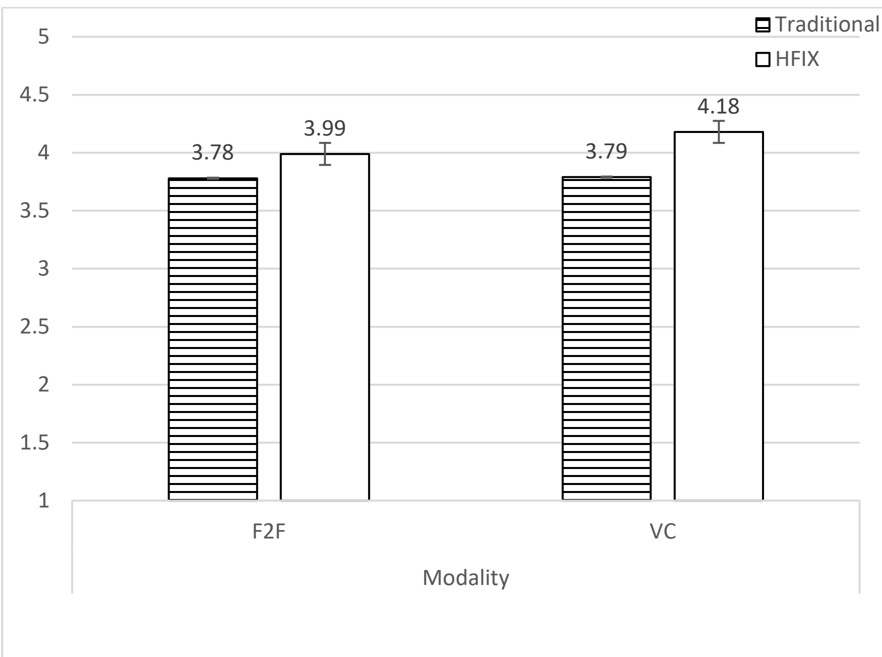

Figure 13. Estimated Marginal Means of Acceptability

Finally, significant interactions between Modality and Brainstorming Type were uncovered for Feasibility (*M* = 3.88, *SD* = 0.84) and Sustainability (*M* = 3.08, *SD* = 0.54) scores.

Table 3 summarizes the descriptive statistics, including each variable's sample size, mean, and standard deviations.

Table 3
Descriptive Statistics for MANOVA

Modality (F2F, VC)			N	Mean	Std. Deviation
Feasibility	F2F	T	252	3.50	0.94
		H	363	3.86	0.77
		Total	615	3.71	0.86
	VC	T	282	4.07	0.78
		H	290	4.06	0.77
		Total	572	4.06	0.77
	Total	T	534	3.80	0.91
		H	653	3.95	0.78
		Total	1187	3.88	0.84
Acceptability	F2F	T	252	3.78	1.03
		H	363	3.99	0.76
		Total	615	3.90	0.88
	VC	T	282	3.79	0.92
		H	290	4.18	0.59
		Total	572	3.99	0.79
	Total	T	534	3.79	0.97
		H	653	4.07	0.69
		Total	1187	3.94	0.84
Cost	F2F	T	252	3.61	0.86
		H	363	3.71	0.79
		Total	615	3.67	0.82
	VC	T	282	4.01	0.78
		H	290	3.99	0.80
		Total	572	3.99	0.79
	Total	T	534	3.82	0.84
		H	653	3.83	0.81
		Total	1187	3.83	0.82
Effectiveness	F2F	T	252	2.95	0.67
		H	363	2.78	0.58
		Total	615	2.85	0.62
	VC	T	282	2.82	0.64
		H	290	2.66	0.65
		Total	572	2.74	0.65
	Total	T	534	2.88	0.66
		H	653	2.72	0.61
		Total	1187	2.79	0.64

Sustainability	F2F	T	252	2.97	0.58
		H	363	3.23	0.54
		Total	615	3.12	0.57
	VC	T	282	3.00	0.49
		H	290	3.07	0.49
		Total	572	3.04	0.49
	Total	T	534	2.99	0.54
		H	653	3.16	0.52
		Total	1187	3.08	0.54

Number of ideas generated in each HFIX category: Hypothesis 3 and Hypothesis 6

Chi-square tests for independence (χ^2) were conducted for the five dependent variables: (Environment, Task, Technology, Individual/Team, and Supervisory/Organization) to test H_{03} and H_{05}. These hypotheses were interested in assessing whether there was an association between the number of interventions generated in each HFIX category when considering both brainstorming type and modality. As shown above, no assumptions were violated (See Chi-square test for independence assumptions).

Dependent Variable: Environment

A significant difference was discovered in the Environment category for the brainstorming technique utilized (χ^2 (1) = 31.53, $p < 0.05$). In addition, a significant difference was also discovered for the Environment category regarding the brainstorming type and modality utilized (χ^2 (3) = 48.81, $p < 0.05$). The effect appears to be driven by the F2F/HFIX condition ($n = 73$).

Dependent Variable: Task

No significant differences were identified between the brainstorming type utilized when generating interventions in the Task category of HFIX (χ^2 (1) = 0.2, *ns*). Similarly, no differences were discovered between the brainstorming type and modality used on the number of ideas generated in the Task category of HFIX (χ^2 (3) = 0.78, *ns*).

Dependent Variable: Technology

A significant difference was found between the brainstorming techniques utilized for the Technology category of HFIX (χ^2 (1) = 5.21, $p < 0.05$). A significant difference was also found between brainstorming type and modality on the number of ideas generated in the Technology category of HFIX (χ^2 (3) = 9.39, $p < 0.05$).

Dependent Variable: Individual/Team

No significant difference was found regarding the brainstorming technique used regarding the individual/team category of HFIX (χ^2 (1) = .97, *ns*). There was a significant association found between brainstorming type and modality on the number of ideas generated in the Individual/Team category (χ^2 (3) = 8.97, $p < 0.05$).

Dependent Variable: Supervisory/Organization

There was a significant difference identified between the brainstorming type used for the ideas generated in the Supervisory/Organization category (χ^2 (1) = 5.16, $p < 0.05$). However, there were no significant associations between brainstorming type and modality on the number of ideas generated in the F2F/T, F2F/H, VC/T, and VC/H conditions (χ^2 (3) = 6.68, *ns*).

Top 10 interventions generated in each of the conditions

The qualitative results show differences in the distribution of interventions generated in the top ten ideas for each condition. As shown in Table 4, the 10 best interventions generated in the F2F/T condition were classified and sorted into the following HFIX categories: individual/team (n = 7), supervisory/organizational (n = 1), environment (n = 1), and technology (n = 1).

Table 4.
Qualitative data: Top 10 Interventions generated in the F2F/T condition

	F2F/T Interventions	HFIX category
1	Verbally praise the kids when they wash their hands (for example: Have teachers say X washed her hands, be like X.)	Individual/Team
2	Buddy system for hand washing (go in pairs).	Individual/Team
3	Make the bathroom pass a stamp on their hands. If they return with a stamp still on their hands, they get sent back to rewash their hands.	Individual/Team
4	Ask the kids if they washed their hands (verbal reinforcement).	Individual/Team
5	Conduct hand checks.	Individual/Team
6	Refuse to let the children leave the bathroom until they wash their hands.	Supervisory/Organizational
7	Designate a hall monitor (class representative) who ensures people wash their hands.	Individual/Team
8	Have a separate kid and adult soap (i.e., Paul Mitchell vs. Mickey Mouse soap) as an incentive to get the kids to wash their hands.	Individual/Team
9	Ensure that the bathrooms are clean and not disgusting, so kids do not bypass/skip washing their hands.	Environment
10	Create songs about washing hands that are created for children (like singing the happy birthday song twice).	Technology

Similarly to the F2F/T condition, the F2F/H group had interventions coded into the individual/team dimension of HFIX (*n* = 4). However, this condition differed in that it had a greater number of ideas in the Environment (*n* = 4) and Technology (*n* = 2) categories of HFIX (See Figure 5).

Table 5.
Qualitative data: Top 10 Interventions generated in the F2F/H condition

	F2F/H Interventions	HFIX category
1	Have bathroom monitors that make sure the kids wash their hands.	Individual/Team
2	Have a teacher stand by the sink and give feedback on hand washing. If they do a good job, they receive praise.	Individual/Team
3	Make sure that the soap dispensers and paper towel holders are full.	Environment
4	Let the kids who wash their hands play with specific toys that the ones who do not wash their hands cannot use.	Individual/Team
5	If they wash their hands correctly, their name will be put in a drawing or pot to win a toy.	Individual/Team
6	Have good-smelling soap available for the kids to use.	Technology
7	Use a soap that makes more bubbles for the kids to wash with (have it make more bubbles the harder they scrub).	Technology
8	Have everything as minimal as possible in the bathroom so the kids do not get distracted.	Environment
9	Don't play annoying music, so you do not annoy the kids trying to wash their hands.	Environment
10	Ensure the soap dispenser is in working order (dispenses soap and is not broken).	Environment

As shown in Figure 6, the top ten interventions in the VC/T condition were coded into the individual/team (n = 6) category of HFIX, with the remaining interventions falling into one of the following categories: technology (n = 3) and task (n = 1).

Table 6.
Qualitative data: Top 10 Interventions generated in the VC/T condition

	VC/T Interventions	HFIX category
1	Positive verbal praise for washing their hands (ensure that the kids who don't wash their hands see you praise the kids who do).	Individual/Team
2	Ask if they washed their hands (like brushing their teeth).	Individual/Team
3	Bathroom buddies who check and remind them to wash their hands (hold each other accountable).	Individual/Team
4	Teach kids about cleanliness.	Individual/Team
5	Put a stamp or temporary tattoo on the kid's hands if they wash them correctly.	Individual/Team
6	Give the kids the opportunity to make their own soap (type of soap (color or smell) to encourage them to wash their hands.	Technology
7	The more they wash their hands, the more activities they can do.	Individual/Team
8	Create a checklist for hand washing to remind them of the steps.	Technology
9	Create a chant to help them remember the handwashing steps (Push, press, and scrub).	Technology
10	Make hand washing a part of the activity they are doing.	Task

Finally, when reviewing the top ten interventions in the VC/H condition, it was found that all ten of the top intervention approaches were sorted into the Individual/Team dimension (*n* = 10) of HFIX (See Table 7).

Table 7.
Qualitative data: Top 10 Interventions generated in the VC/H condition

VC/H Interventions	HFIX Category
Make handwashing habitual (every time they come in from recess, they must wash their hands).	Individual/Team
Reinforce what it means to wash their hands weekly (one person shows).	Individual/Team
Establish handwashing as an important process at a young age.	Individual/Team
Repeat and raise awareness to get the kids to wash their hands.	Individual/Team
Have a supervisor (teacher or parent) ensure the kids wash their hands correctly.	Individual/Team
Put confidence in the kids who have to go to the bathroom and say, "you know what to do." Make the kids feel important and independent!	Individual/Team
Teach the kids how not washing their hands can make them sick. (Teach them about germs).	Individual/Team
Make an acronym for the kids to learn regarding handwashing.	Individual/Team
Handwash debrief with the child (What did they do right? Wrong?)	Individual/Team
Do a praise system for the kids who wash their hands (get a gold star if they wash their hands).	Individual/Team

Chapter Five: Discussion

The current project focused on utilizing and validating the Human Factors Intervention Matrix and the companion assessment tool FACES regarding developing and ranking novel interventions. The study was interested in uncovering whether or not brainstorming with HFIX would generate a higher quantity, a better quality, and a wider breadth of ideas than traditional brainstorming. It also focused on whether the modality in which HFIX was used affected the quantity, quality, and breadth of ideas generated.

Summary of Results

Before diving further into the findings, Table 8 contains a synopsis of the results presented in the prior section of this dissertation.

Table 8.
Summary of Results

Hypothesis	Findings
Brainstorming with HFIX will generate a higher quantity of ideas than traditional brainstorming.	Participants in the HFIX conditions generated more interventions than participants in the traditional brainstorming conditions.
Brainstorming with HFIX will generate higher quality ideas than traditional brainstorming.	Participants in the HFIX conditions generated interventions that were considered more feasible, acceptable, and sustainable. Participants in the traditional brainstorming conditions generated interventions that were considered more effective.
There will be a difference in the number of ideas generated within each of the categories of HFIX when comparing brainstorming with HFIX to traditional brainstorming.	Participants in the HFIX conditions generated more interventions in the Environment, Technology, Individual/Team, and Supervisory/Organizational categories of HFIX than participants did in the traditional brainstorming groups. No associations were found for Task.
Brainstorming with HFIX via VC will generate a higher quantity of ideas than brainstorming with HFIX F2F.	Participants in the F2F/H condition generated more interventions than participants in the F2F/T, VC/T, and VC/H conditions.
Brainstorming with HFIX via VC will generate a higher quality of ideas than brainstorming with HFIX F2F.	Participants generating ideas F2F created interventions that were considered more effective and sustainable. Participants generating ideas via VC created interventions that were considered more feasible and cost-effective.

There will be a difference in the number of ideas generated within each of the categories of HFIX when comparing the modality in which HFIX is used (F2F and VC).	Participants in the F2F/H condition generated more interventions in the Environment and Technology categories of HFIX than the other conditions. Participants in the VC/T condition generated more interventions in the individual/team category of HFIX than the other conditions. No associations were found for Task and Supervisory/Organization.

Will brainstorming using HFIX generate a higher quantity, quality, and breadth of ideas compared to traditional brainstorming?

The effect that brainstorming type has on quantity

While organizations have a suite of tools at their disposal to identify underlying human factors issues that contribute to accidents, creating, implementing, and ensuring that quality interventions succeed is still a significant challenge (Cohen et al., 2005; Ergai et al., 2015). Typically, when companies adopt solutions to address the problem, they focus on adding/modifying training, implementing new policies/procedures, or firing the “problem” personnel. In an attempt to get participants to think outside the box and step away from implementing those “traditional” solutions, multiple IGTs have been created (Higgins, 2005). As a result, people have options when trying to develop novel and creative interventions.

One IGT of particular interest in this dissertation is brainstorming. Brainstorming took the world by storm during its inception and has stayed a popular technique currently used by organizations to generate interventions (Al-Samarraie & Hurmuzan, 2018; Lehrer, 2012). Previous literature defines brainstorming as the process in which members work together to develop as many solutions as possible (Osborn, 1957, pp 151-152). The brainstorming process (as described above) is typically broken down into two main phases: 1. The idea generation phase and 2. The idea evaluation phase (Gabora, 2018;

Piffer, 2012). The first research question regarding whether brainstorming with HFIX (a new IGT) generates a higher quantity of interventions is focused explicitly on the idea generation phase of the brainstorming process.

Several studies have explored the effect brainstorming quantity has on the idea generation process (Feinberg & Nemeth, 2008; Lewis et al., 1975; Miller, 2009; Mohammad & Hussein, 2013; Parnes & Meadows, 1959; Putman & Putman, 2009). For example, previous research has discovered that in specific settings, such as the classroom, traditional brainstorming can increase the number of ideas created (Parnes & Meadows, 1959), while others have demonstrated that utilizing brainstorming techniques is highly context-dependent, can produce fewer ideas overall, and can at times be ineffective in generating creative solutions in a timely manner (Miller 2009; Putman & Putman, 2009; Sparrey, 2020).

The results revealed that brainstorming type did affect the quantity of interventions generated within the groups. More specifically, using HFIX during the brainstorming process helped participants develop 73 more ideas than their virtual counterparts (VC/H condition). These results echo prior findings regarding the positive effect that semi-structured brainstorming techniques can have on idea generation (Gero, Jiang, & Williams, 2013; Nijstad, Stroebe, & Lodewijkz, 2002).

The particular interventions generated in the F2F condition were varied and included ideas such as “verbally praising the kids if they washed their hands,” “creating a buddy system for handwashing,” “making sure that the soap dispensers and paper towel holders are full/in working order,” “making the kids sick if they do not wash their hands (infect them), and “sending the kids to Military school so they are constantly watched”. The VC condition on the other hand generated interventions such as: “make handwashing a habit,” “raise handwashing awareness to get kids to wash their hands,” “implement a praise system for the kids who wash their hands,” “have a handwashing station that is covered in glass that will only open if a kid is present,” and “make the soap edible so that the kids can wash their hands and then eat it". As shown in the examples above, participants in the HFIX and Traditional brainstorming conditions, generated an interesting mix of interventions (albeit some wilder and crazier than others). While the F2F/H condition generated more interventions overall, it is not yet clear whether the interventions generated within the conditions covered a wider breadth of ideas and were of better quality than the traditional brainstorming techniques. Therefore, the breadth of ideas generated and quality of the interventions generated in each of the conditions was investigated using the HFIX and FACES frameworks.

Effect that brainstorming type has on the breadth of interventions generated

After the idea generation process ended, the next step was to classify and evaluate the generated interventions. In order to systematically sort the created interventions, researchers utilized the HFIX framework (Shappell & Wiegmann, 2006). The Human Factors Intervention Matrix (HFIX) provides a methodology for identifying prospective interventions and ensuring that the most expansive assortment of interventions is considered to address the identified problems. This framework tackles problems from five dimensions: Environment, Task, Technology, Individual/Team, and Supervisory/Organization. Three independent researchers coded the generated interventions into the HFIX framework described above.

Results indicate that utilizing HFIX to brainstorm helped participants generate more interventions in the Environmental category than participants who used traditional brainstorming. More specifically, participants in the HFIX condition created 69 more interventions than the traditional brainstorming condition. Interestingly, the HFIX conditions not only generated significantly more environmental interventions overall than the traditional brainstorming groups but had more of the generated interventions make it into the top ten interventions list. For example, instead of participants just focusing on cleaning the bathroom (as shown in the traditional brainstorming interventions), participants in the HFIX condition started generating interventions like changing the bathroom's layout and adjusting the temperature and lighting. These results reveal that HFIX can help participants think outside of their wheelhouse and echoes Bronfenbrenner's (2005) model and social-ecological theory that postulated that effective interventions should in some way address the environment in which the students live.

Participants in the HFIX condition were also found to have generated more ideas in both the Technology and Supervisory/organization categories of HFIX than the Traditional brainstorming conditions. Results show that participants in the HFIX condition generated 49 more technological interventions, and 28 more supervisory/organization interventions than participants in the traditional brainstorming condition. The outcomes echo previous literature showing that the brainstorming problem can affect the type of ideas generated (Al-Samarraie, H. & Hurmuzan, S., 2018). More specifically, the topic and wording of the brainstorming problem could prompt/lend itself to ideas generated in specific categories (Hackman & Morris, 1976). On top of that, Hackman and Morris (1976) postulate that groups tend to pool their resources (i.e. personal background as well as outside prompts/aids) to generate solutions when the problem is complex or challenging. The demographic results, in this case, show that over 90% of participants majored in either social science, science, or aviation. So, it is not surprising that significant differences were found between the brainstorming type and the number of ideas generated in each of the following HFIX categories: Technology and Supervisory/Organization. It seems that utilizing HFIX helped participants (regardless of the modality used) begin to think beyond the wheelhouse that they normally use to generate ideas.

Finally, no significant associations regarding brainstorming type were found for the following HFIX categories: task and individual/team. Hackman and Morris (1976) and Wang (2019) explain that when the brainstorming question is considered easy, the group has less use for checklists that are supposed to help prompt them to think outside their box. In a way, easy questions lull the participants into thinking that they are generating an exhaustive list of interventions from all directions, when in reality they are just generating ideas based on what their background is in (which is what was seen with the participants in this study) (Shih, Venolia, & Olsen, 2011). Future research should be done to see the effect of question type and difficulty on the idea generation process (regarding idea quantity and then idea breadth) when utilizing HFIX.

Effect that brainstorming type has on quality

Once the idea generation stage of the brainstorming session has been completed, there are numerous created interventions to wade through and choose from. The next step is to move into the second stage of the brainstorming process, known as the idea evaluation stage (Gabora, 2018; Piffer, 2012). This stage is focused on assessing and selecting an accurate solution based on constraints, assumptions, and pros/cons analyses. Currently, there is no gold standard in the literature regarding selecting the "final" best intervention/s. In an ideal world, one would hope that participants would review all of the generated interventions and then decide upon the "best" solutions. Prior research has revealed that when it comes to selecting the "best" solutions, participants do not review the entire list (i.e., they tend to choose ideas generated early in the list) and prefer to pick interventions that are feasible rather than interventions considered to be original (Johnson and D'Lauro, 2018). More specifically, research has shown that participants do not review all of the interventions and are biased in their ranking (i.e., participants tend to choose practical interventions over potentially better ideas; Rietzschel, Nijstad, & Strobe, 2006a; Rietzschel, Nijstad, & Strobe, 2006b).

Fortunately, Shappell and Wiegmann (2006) created an intervention system called FACES. FACES is an acronym for an intervention ranking system that stands for 1. Feasibility, 2. Acceptability, 3. Cost, 4. Effectiveness, and 5. Sustainability. Feasibility refers to whether or not the change can be employed easily and quickly (i.e., can it be done?). Acceptability refers to whether or not the frontline personnel will readily accept the change (i.e., will operators accept it?). Cost refers to whether or not the benefit outweighs the cost (i.e., can we afford it?). Effectiveness refers to how well the intervention will solve the problem (i.e., will it work?). Finally, sustainability refers to how well the intervention will last over time (i.e., will it last?). At the end of the idea generation process, subject matter experts (SMEs) are directed to rate each intervention on a 5-point Likert scale where 1 indicates "low" and 5 indicates "high." The scores for each category are then added to give a total score that can help researchers quantitatively determine which interventions should be selected for implementation (Shappell and Wiegmann, 2006). The higher the FACES score, the "better" the intervention.

Interestingly, there were differences in the quality of interventions generated when comparing brainstorming with HFIX to Traditional brainstorming. First, participants utilizing HFIX developed interventions that were considered more feasible compared to traditional brainstorming. Runyan (1998) stated that intervention feasibility has several dimensions to consider (such as technological feasibility, cost, etc.) and is essential when selecting interventions. Previous literature has revealed that participants tend to want to generate feasible interventions rather than creative ideas (Rietzschel, Nijstad, & Strobe, 2006b). Next, participants generating interventions with HFIX created interventions that were considered more acceptable and sustainable when compared to traditional brainstorming. These results echo prior brainstorming research that shows both acceptability and sustainability being essential factors to the overall success of the selected interventions (Ayal & Elder, 2011). In line with prior research, these results show that utilizing HFIX (a structured brainstorming technique) seems to ground participants and help them generate feasible interventions that will be accepted by the organization and last over time.

In contrast, the results also revealed that participants in the traditional brainstorming group generated interventions considered to be more effective than the HFIX group. This finding is interesting because prior research into "effectiveness" reveals that while it is vital, effectiveness alone (without information on its feasibility, cost, and acceptability) should not be what is solely used to decide whether or not to implement an intervention (Evans, 2002). An example of an effective solution that is not acceptable or sustainable over time would be "shocking the children to get them to wash their hands." It may work to get the kids to wash their hands the first few times; however, there would be pushback from society, and it is doubtful that the children will continue to respond to that stimuli positively.

Finally, although prior research has revealed that cost is an important factor to consider when selecting interventions, no differences were found for cost (Hastings, Merriken, & Johnson, 2000). The lack of findings regarding cost could result from the topic and difficulty of the brainstorming problem (brainstorm ways to get children to wash their hands after going to the bathroom; Hastings, Merriken, & Johnson, 2000; Johnson, Sian, & Watson, 2000). Many of the interventions generated to address the handwashing problem were relatively low-cost intervention approaches, such as: "praising the children," "generating checklists to help children remember the handwashing steps," and "supervising the children to make sure they wash their hands." On the other hand, some of the interventions were considered to be highly excessive relative to their minimal expected impact on the brainstorming problem. For example: "Drug the kids through the food or water and make them addicted to handwashing," and "Have a designated kid sink for each child." These interventions were deemed to be too expensive for the relative impact that they would make on getting children to wash their hands.

Summary

This study has shed light on the effect brainstorming with HFIX has on idea quantity, quality, and breadth of ideas when compared to traditional brainstorming. More specifically, it was found that brainstorming with HFIX generated more interventions overall than traditional brainstorming. Participants in the HFIX conditions produced interventions that were considered to be more feasible, acceptable, and sustainable. In addition, participants in the HFIX conditions created more interventions in the Environment, Technology, and Supervisory/Organization categories of HFIX than the traditional brainstorming groups. Finally, results show that participants in the traditional brainstorming condition generated interventions that were considered more effective. The jury is still out on the effect that HFIX has on idea generation. With this study being the first to validate HFIX and its companion tool FACES, more research is needed to truly understand the relationship between brainstorming type on idea generation quantity, quality, and breadth.

Does the modality in which HFIX is used affect the quantity, quality, and breadth of ideas created?

Effect that modality has on quantity

Today, there are three main ways to generate interventions utilizing brainstorming: traditional brainstorming, nominal brainstorming, and electronic brainstorming (VC, AC, and CMC). Of particular interest in this study are traditional and electronic brainstorming. Traditional (F2F) brainstorming stays true to Osborn’s four rules of brainstorming (See Appendix H) as interventions are being generated; while electronic brainstorming, more specifically, VC, uses tools such as Microsoft Teams© to help remotely facilitate idea generation in real-time within the group (Osborn, 1957).

It was hypothesized that brainstorming with HFIX via VC would generate a higher quantity of ideas than brainstorming with HFIX F2F. Results revealed that participants in the F2F condition generated more interventions than the VC condition. More specifically, the F2F/H condition generated more interventions than participants in the F2F/T, VC/T, and VC/H conditions. Within the literature, research regarding modality's effect on idea generation is rather conflicting. When comparing traditional brainstorming to EBS (i.e., brainstorming via VC), the current literature reveals that EBS has the potential to outperform traditional and nominal brainstorming both in quality and quantity of ideas generated (Dennis & Valacich, 1993, 1994; Valacich et al., 1994; Ziegler et al., 2000). In addition, EBS is believed to help mitigate some of the social factors that can often affect a participant's willingness to create ideas F2F (i.e., social loafing, evaluation apprehension, etc.; Dennis & Valacich, 1993; Dennis & Williams, 2005; DeRosa et al., 2007; Ziegler et al., 2000).

However, this is not always the case, as shown by the results above and Kohn and Colleagues (2011), who discovered that groups utilizing EBS generated fewer combinations. More specifically, the F2F/H group generated 363 interventions compared to the final totals for the F2F/T (n = 252), VC/T (n = 282), and VC/H (n = 290) conditions. As Wang (2019) postulated, the contradictory results may show that brainstorming is highly dependent upon the setting/organization in which it is utilized, the individuals' knowledge of the subject matter, and the nature of the brainstorming task.

One potential explanation for the lack of findings is that while the participants were asked to pay attention, they were wearing masks and were not in the same room as the researcher for the study duration. This means that participants could have easily been working on other tasks, been distracted by the environment in which they were working in, or been disengaged by the fact that the masks were covering up facial/body cues that one would use when talking in groups (Henningsen & Henningsen, 2013). While the F2F/H condition generated more interventions overall, the next step was to see the distribution of ideas for each condition.

Effect that modality has on the breadth of interventions generated

As shown in the "Effect that brainstorming type has on the breadth of interventions generated" section, once the idea generation phase was completed, the created interventions were sorted into the "best fitting" HFIX category. The Human Factors Intervention Matrix provides a framework for identifying interventions and helps ensure that the most expansive assortment of interventions is considered when addressing the problem. In other words, it was believed that when using the HFIX checklists/process, the interventions generated would span across more categories, allowing the users to tackle the problem from multiple directions.

Results indicate that participants in the F2F conditions generated 39 more environment interventions than participants in the VC conditions. More specifically, the F2F/H condition was found to have developed significantly more interventions than the other three conditions (F2F/T, VC/H, and VC/T). These results echo previous findings regarding F2F brainstorming (in a classroom setting) increasing the number of ideas created (Parnes & Meadows, 1959). Researchers found that not only did the F2F/H condition generate more environmental interventions, but more of the generated interventions made it into the top ten interventions list for that condition (F2F/T- 10%; F2F/H- 40%; VC/T- 0%, and VC/H- 0%).

Additionally, participants in the F2F/H condition also generated more interventions in the technology category of HFIX than the other three conditions. Interestingly, while the technology category had the most ideas generated ($n = 461$) there were very few interventions that made it into the top ten for each condition (F2F/T- 10%; F2F/H- 20%; VC/T- 30%, and VC/H- 0%). These interventions focused mainly on "having the soap bubbles be harder to scrub off," "creating a checklist for the kids to use," and "creating chants to help them remember the hand washing steps."

Next, it was revealed that participants in the VC/T condition generated more interventions in the individual/team dimension of HFIX than the other three conditions. In fact, most of the interventions in the top ten for each condition belonged to/were coded into the individual/team dimension of HFIX (F2F/T- 70%; F2F/H- 40%; VC/T- 60%, and VC/H- 100%). These interventions focused mainly on "utilizing bathroom buddies," "training/teaching the kids about cleanliness," and "asking/checking on whether or not the kids washed their hands." Finally, no associations were present for the following HFIX categories: task and supervisory/organization. In fact, in the top ten intervention approaches for each condition, there was only one represented idea for both supervisory/organization and task (e.g., refuse to let kids leave the bathroom until they wash their hands; and make handwashing a part of their task).

With the majority of the students majoring in a social science or science field, these results are not surprising. Participants utilized the background and knowledge that they have for those topics when they were generating interventions for the problem at hand. These results begin to paint a picture that at least when participants are F2F, HFIX can start to help them think outside of their wheelhouse.

Researchers believe that the results regarding the number of interventions generated in the following HFIX categories could have been affected by the brainstorming question (getting children to wash their hands after going to the bathroom) for which participants were asked to create solutions. Prior research has shown that the brainstorming question can affect the interventions generated (Al-Samarraie, H. & Hurmuzan, S., 2018). Anecdotally, participants struggled less when developing interventions for the proposed problem in categories like individual/team, technology, and environment than task and supervisory/organization, which is believed to be due to the amount of knowledge and experience that the participants had regarding those topics.

Former research regarding the effect checklists have on idea generation in different modalities has revealed that participants generating ideas via VC can affect the number of interventions developed and that it is highly reliant upon the organization, the individuals' subject knowledge, and the nature of the task (Wang, 2019).

Effect that modality has on quality

Now that the idea generation stage has concluded, the next step is to move on to the idea evaluation stage (Gabora, 2018; Piffer, 2012). Unfortunately, as discussed above, there is no gold standard in the literature regarding selecting the “final” best intervention. Often, participants select a solution at the beginning of the list that is considered feasible instead of reviewing all options and selecting the best solution (Johnson and D'Lauro, 2018). One potential answer to this problem is utilizing an intervention system like FACES to help quantitatively determine which ideas are better (Shappell & Weigmann, 2006).

When evaluating quality, researchers have focused on different aspects of quality corresponding to their particular task, such as feasibility, novelty, effectiveness, the value ideas could create, the importance of an idea within a specific context, as well as the magnitude of impact an idea might have (Diehl & Stroebe, 1987; Diehl & Stroebe, 1991; Fjermestad & Hiltz, 1999). As previously stated, the research regarding EBS and F2F brainstorming is mixed. Prior research suggests that EBS should outperform F2F traditional brainstorming regarding the quantity and quality of ideas being generated (Dennis & Valacich, 1993, 1994; Valacich et al., 1994; Ziegler et al., 2000). In contrast, other studies have found that in specific settings, similar to traditional and nominal brainstorming, electronic brainstorming generated fewer combinations (Kohn et al., 2011) and was not found to produce an increase in quality (Paulus, Dugish, Dzindolet, Coskun, & Putman, 2002).

The current results show a difference in the quality of ideas when accounting for the modality utilized. First, participants in the VC conditions generated interventions considered more feasible than F2F. This finding echoes previous literature where EBS outperforms traditional brainstorming regarding the quality of interventions developed (Dennis & Williams, 2005). Participants in the VC condition were also found to have generated more cost-effective interventions than the F2F conditions. Prior research has shown that money and safety (i.e. the cost/benefit) are essential factors to consider during the idea ranking stage and are linked to developing effective interventions (Hastings, Merriken, & Johnson, 2000; Johnson, 2006).

The F2F conditions, on the other hand, generated interventions considered to be more effective and sustainable than the VC conditions. These results mirror previous research regarding the fact that

F2F brainstorming can generate higher quality interventions than other modalities (such as VC) but is highly dependent on the setting/organization in which it is completed, the individuals' knowledge of the subject matter, and the nature of the imposed creativity task (Wang, 2019). Finally, no differences in the modality being used were found for acceptability. Overall, the four conditions had very similar acceptability scores, which echoes previous literature regarding the fact, that participants generate acceptable interventions regardless of the modality in which they are being created (Ayal & Elder, 2011).

With this study being the first to validate HFIX and its companion tool FACES, more research is needed to truly understand the relationship between the brainstorming type and modality on idea generation quality.

Summary

This part of the study was interested in shedding some light on the effect that brainstorming modality has on idea quantity, quality, and breadth of ideas. It was revealed that participants in the F2F condition generated more interventions than the VC condition. More specifically, participants in the F2F/H condition generated more ideas than the other conditions. Participants generating ideas F2F created interventions that were considered more effective and sustainable, while participants in the VC conditions developed more cost-effective and feasible interventions. Finally, participants in the F2F/H condition generated more interventions in the Environment, Technology, and Individual/team categories of HFIX, while participants in the VC/T condition generated significantly less. These results echo previous literature and open the door to studying modality's effect on idea generation quantity, quality, and breadth.

Limitations and Future Work

All research has limitations, and the current dissertation is no exception. While this dissertation addressed the hypotheses proposed above, there are several limitations that should be addressed.

The first limitation in this study is directly related to the laboratory setting in which the ERAU university students were randomly assigned to and participated in ad hoc groups. While conducting investigations in a laboratory setting has advantages (i.e., allowing for variables that otherwise could affect the study to be held constant), it also has limitations. For example, we do not know whether the behavior of the university students in this short-term setting can truly be generalized to the behavior/output of the employees at a workplace where career success and promotion would be at stake (i.e., employees may have more buy-in to solve the problem).

Another potential limitation of this study is that most of the students self-selected to participate in the study for extra credit in one of their classes. In an attempt for researchers to mitigate the self-selection bias, participants were randomly assigned to groups and conditions. There is, however, still a possibility that since the individuals volunteered to participate, they may have had extra interest in completing/solving the problem, which could have affected the amount of effort they were willing to put into the study.

The third limitation is related to the HFIX training. At the beginning of the study, participants were shown a training video that introduced them to HFIX and walked them through a practice problem. It is possible that only having the participants watch the training video was not enough to get them to understand how to utilize HFIX effectively during the brainstorming process. Should participants be asked to watch that introduction to HFIX video and then be led in real-time through a practice brainstorming problem before they start brainstorming for the selected issue?

The fourth limitation of this study is that we were collecting data during a pandemic, so participants were asked to wear masks during their sessions. Previous research has shown that faces convey essential information regarding identity and emotion that could have been lost during our brainstorming session. In an attempt to control for this, researchers had all participants, regardless of condition, wear a mask.

Finally, future work is needed to determine the true effects of HFIX and its companion tool FACES on the brainstorming process. More specifically, research is required to address the following questions: 1. Do different participant ranges (i.e., people with different careers who are directly affected by the problem they are generating solutions for) affect idea generation, 2. How do various problems (hard vs. easy) affect the idea generation process when utilizing HFIX, and 3. What is the ideal group size and composition for groups wanting to use HFIX?

Conclusion

As previously discussed, there is a lack of research regarding a unified process of systematically developing and ranking/choosing interventions within a system. It is believed that HFIX and FACES could be the answer that the field is looking for. This dissertation utilized and validated the Human Factors Intervention Matrix and the companion assessment tool FACES regarding developing and ranking novel interventions. The present study looked to uncover the relationship between brainstorming type (i.e., HFIX and Traditional) and Modality (i.e., F2F and VC) on idea quantity, quality, and breadth of ideas. Based on the results of this experiment, the jury is still out on whether using HFIX while brainstorming positively affects the quantity, quality, and breadth of ideas. While it seems like using HFIX helps generate interventions, more research is needed to determine the effect that HFIX has on the idea generation process.

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Appendices

Appendix A – Informed Consent Form

Purpose of this Research: The purpose of this study is to determine the effect of brainstorming techniques on idea generation.

Specific Procedures:
During this study, you and two others in your group will be: given a brief demographic survey, introduced to brainstorming, and asked to brainstorm solutions to a proposed problem. Completion of the study will take approximately an hour and fifteen minutes.

Eligibility: To be in this study, you must be a student at Embry-Riddle Aeronautical University over the age of 18.

Benefits: This research will allow us to begin to understand the effect that specific brainstorming techniques have on group idea generation.

Risks or Discomfort: It is anticipated that this study will pose no greater risk than you would experience through normal daily activities.

Confidentiality of records: Your individual information will be protected in all data resulting from this study. Your responses during the study and within the surveys will be anonymous. No personal information will be collected other than basic demographic descriptors. The online survey system that we are using will not save IP addresses or any other identifying information. In order to protect the anonymity of your responses, we will keep your responses in a password-protected file on a password-protected computer. No one other than the researchers on this study will have access to any of the responses.

Compensation: By participating in this study, you will receive 1 credit in SONA. If you begin the study and decide to discontinue during the study, you will still receive 1 credit.

Contact: If you have any questions or would like additional information about this study, please contact the Primary Investigator: Victoria Lew, Lewv@my.erau.edu, or the faculty member overseeing this project, Dr. Shappell, Shappe88@erau.edu. For any concerns or questions as a participant in this research, contact the Institutional Review Board (IRB) at 386-226-7179 or via email teri.gabriel@erau.edu.

Voluntary Participation: You do not have to participate in this study. If you agree to participate, you can withdraw your participation at any time without any penalty or repercussion. Furthermore, if you withdraw from the study prior to its completion, your data will be destroyed immediately.

CONSENT. By signing below, I certify that I am a college student, a resident of the U.S. and I am 18 years of age or older. I further verify that I understand the information on this form, that the researcher has answered any and all questions I have about this study, and I voluntarily agree to participate in the study.

A copy of this form can be requested from the Primary Investigator: Victoria Lew, Lewv@my.erau.edu.

____

Signature

Appendix B – Demographics Survey

1. Current Age
    a. _____________.
2. Gender
    a. Female
    b. Male
    c. Other
    d. Prefer not to say
3. What is your ethnicity?
    a. White
    b. Hispanic or Latino
    c. Native American or American Indian
    d. Asian/Pacific Islander
    e. Black/African American
    f. Other (please specify)
4. What is your current Academic standing
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Graduate Student
5. What is your major?
    a. Engineering & Engineering Technology
    b. Business, Marketing, or Economics
    c. Social Sciences (e.g., Human Factors, Homeland Security, Global Studies, etc.)
    d. Science (e.g., Biology, Chemistry, Computer Science, etc.)
    e. Humanities (e.g., History, English, Arts, etc.)
    f. Aviation (e.g., Air Traffic Control, Unmanned Arial Systems, Flight, etc.)
    g. Other (fill in the blank on the next question)
6. What is your current Major? (ONLY FILL OUT IF YOU DID NOT SELECT A MAJOR ON THE PREVIOUS QUESTION)
    a. _________________.

Appendix C – HFIX Checklists
(Scott Shappell & Doug Weigmann, HFACS Inc.)

ENVIRONMENT FACTORS

(Refers to physical working environment in which individuals and teams perform their activities)

When considering ways of modifying the physical working environment, ask yourself…

- ❑ How could the number of distractions in the environment be reduced to allow the operator to focus attention more fully on the task?
- ❑ How could workspace arrangements or dimensions be modified to improve task performance?
- ❑ How could the workspace be made suitable for the range of individuals who will use the facility?
- ❑ How could lighting be changed to reduce shadows, glare, or stark lighting changes (e.g., going from light to dark settings)?
- ❑ How could the noise level be modified or reduced to reduce fatigue, improve concentration or enhance communication?
- ❑ How could the temperature conditions be modified or improved to improve concentration, mood, or performance?
- ❑ How could physical/technological barriers to performance or communication be modified or rearranged?
- ❑ How could the physical arrangement of workspaces/rooms be standardized to reduce confusion, delays or errors?
- ❑ How could floor surfaces be modified or improved to allow for better movement or rearrangement of equipment when needed?
- ❑ How could clutter be reduced or housekeeping improved to make the working environment more conducive to safe and productive work?

TASK FACTORS

(Refers to the nature of the activities performed by individuals and teams)

When considering ways of modifying the tasks or activities people perform, ask yourself…

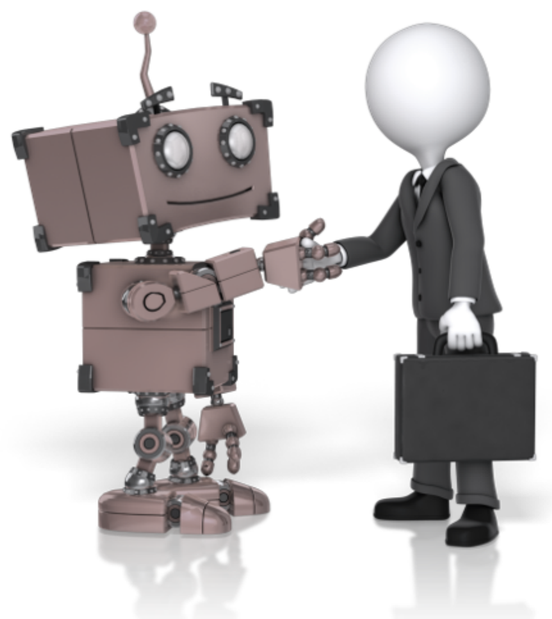
- ❑ How can the task be restructured so that it requires less reliance on human memory (i.e., use checklists or technology that signals next step in task)?
- ❑ If the task is done simultaneously with other tasks (divided attention), can it be done by itself? How can the mental workload/timesharing be reduced?
- ❑ How could errors in performing the task be reduced by having another team member check/verify important steps in the procedure?
- ❑ How could checklists be developed to guide the task or verify that the task has been performed properly?
- ❑ How could immediate feedback be integrated into the task to allow operators to know when they have done things correctly or incorrectly?
- ❑ How can procedures or checklist be redesigned to be clearer or more user-friendly?
- ❑ If the task allows for easy short-cuts, how could it be redesigned to eliminate these shortcuts or reduce the likelihood that they are done?
- ❑ How could procedures be re-written so that they are less ambiguous or inapplicable to the safety critical tasks operators perform?
- ❑ How could procedures be developed that restrict the performance of safety critical tasks when there is time pressure to complete it?
- ❑ When operators switch tasks, what procedures could be developed to reduce negative transfer (habit interference)?
- ❑ If compliance with safe work practices goes unrewarded, how can a reward system be developed to ensure that compliance is reinforced?
- ❑ If a task is repetitive, monotonous, or boring, how could it be made more interesting? How could "time on task" be changed to reduce vigilance decrements or mental lapses in attention?
- ❑ Could operators be rotated off the tasks, checked for errors, or monitored more closely?
- ❑ Could the pacing or ordering of a particular task be modified to reduce opportunities for error?
- ❑ How could a task be modified to reduce the demands on the operator's physical or perceptual limitations?
- ❑ How could the task be redesigned so that its requirements are within reasonable bounds/limits of all persons performing the job (e.g., force, speed, precision, requirements, etc.)?
- ❑ Are the various tasks performed appropriately grouped into jobs? How could similar tasks be more effectively grouped/assigned to operators so that they are performed by operators with the same skills?

TECHNOLOGICAL FACTORS

(Refers to the equipment, tools, software and documents used to perform their work)

When considering ways of modifying technological factors, ask yourself…

- How can warnings or alarms be improved to increase operators' awareness of hazards or the presence of abnormal conditions?
- How can tools or technologies be redesigned to enter into "failsafe" mode when problems occur?
- How could safeguards or personnel protective equipment be improved to reduce the consequences of errors?
- How could tools, checklists, manuals or displays be redesigned to reduce confusion and errors? (e.g., bold face items in checklist that are most important and/or should be memorized).
- How could automation help in reducing the dependency on human performance of certain tasks?
- Are better tools currently on the market but not purchased by the company? What are these tools and how would they reduce errors on the job?
- How could technologies be developed to reduce the task demands on the human decision making processes, perceptual processes, or physical limitations?
- How could operator tools be more effectively designed to improve operator performance and/or reduce injuries?
- How could controls be more easily identified, and/or better designed in terms of shape, size and other relevant considerations?
- How could information sources be integrated or located in a more effective manner?
- How can system redundancy be improved for critical functions, for example better backup or parallel components (persons or machines).
- How could the design/operation of tools, workplaces, vehicles, etc, be standardized to prevent negative transfer or confusion?
- How could tools/technology be developed to reduce the physical demand on the operator?
- How could equipment be redesigned for convenient maintenance?
- How could inspection or troubleshooting aids be developed to ensure equipment is in proper working condition?
- How could maintenance procedures or schedules be improved to prevent equipment from failing during use?



Individual and Teamwork Factors

(Refers to the characteristics of the individuals and teams performing work related activities)

When considering ways of modifying individual and teamwork factors, ask yourself…

- ❑ How could changes be made to the way in which individuals are recruited or selected for employment to ensure that they have the appropriate knowledge and skills necessary to perform their required tasks safely and efficiently?
- ❑ How could individual's motivation to perform their tasks safely be improved or incentivized?
- ❑ How could the content of training programs be developed or modified to improve individual's knowledge of procedures or tasks?
- ❑ How can the method of training delivery be improved or modified to enhance its impact on individual's knowledge and skills (e.g., use of simulation)?
- ❑ How could individual's retention and compliance with new policies and procedures be better monitored and evaluated (e.g., recurrent testing or drills)?
- ❑ How could individual's stress and fatigue be reduced or monitored to improve safety and performance?
- ❑ How could individuals readiness or "fitness for duty" be improved or monitored at the beginning and throughout their shift?
- ❑ How could individual's decision-making or situation awareness be improved to reduce errors (e.g., decision aids or better information)?
- ❑ How could verbal communication procedures be improved to reduce the likelihood of miscommunication among team members (e.g., standardization of phraseology or readback/callback procedures)?
- ❑ How could the use of non-verbal communication (e.g., gestures or hand signals) be developed and standardized to improve communication?
- ❑ How could team briefings/planning sessions be developed or improved to improve communication and coordination?
- ❑ How could debriefings be used or developed to help team members share experiences and learn from their past activities together?
- ❑ How could crew pairing procedures be improved to ensure crew compatibility, in terms of experience, personality, language, or other critical factors?
- ❑ How could procedures be developed to improve the interactions among team members, such as empowering inexperienced operators to challenge experienced operators on safety critical issues?
- ❑ When individuals are working as a team, how could the responsibilities of each team member be more clearly defined?
- ❑ How could changes be made to ensure that team leaders are identifiable and responsible?
- ❑ How could handoffs/handovers be developed or improved to benefit the communication and transition among team members?
- ❑ How could team membership be standardized to ensure adequate familiarity and communication among team members?
- ❑ How could the integration of new team members into the group be enhanced to ensure good communication and coordination?
- ❑ How can the timing of communication be modified so it does not distract or overburden individuals involved (e.g., "sterile cockpit" rule)?

Supervisory and Organizational Factors

(Refers to the management, guidance and oversight of individuals and teams by those in positions of authority at the middle and senior leadership levels)

When considering ways of modifying supervisory and organizational factors, ask yourself…

- ❑ How could the selection and/or promotion of supervisors be improved to enhance the quality of front line supervision?
- ❑ How could methods be developed to improve supervisors' communication with their staff?
- ❑ How could incentives be implemented to encourage supervisors to be more actively concerned or involved in safety issues in their unit?
- ❑ How could changes be made to better empower supervisors to correct problems or address concerns?
- ❑ How could training or experience of supervisors be modified to improve supervisory oversight and planning?
- ❑ How could supervisory involvement and oversight/monitoring be improved to impact safety?
- ❑ How could production pressures on supervisors be changed to reduce the impact on unsafe acts?
- ❑ How could the awareness and appreciation of hazards and risk by supervisors be enhanced?
- ❑ How could standard operating procedures (SOP's) be modified to reduce risks and improve safety?
- ❑ How could the organization and/or supervisor ensure that SOP's are in place and that they are relevant and not out-of-date?
- ❑ How could operational risk management procedures be implemented to reduce safety hazards?
- ❑ How could tools for helping supervisors plan activities and set goals be improved?
- ❑ What tools or job aids could be developed to help supervisors create schedules, improve team composition or reduce operator fatigue?
- ❑ How could the organization change it processes for holding supervisors accountable for enforcing the rules?
- ❑ How could the organization improve its process for recruiting and hiring people who are better qualified or more experienced?
- ❑ How could the organization improve its process for evaluating and purchasing equipment that is user friendly and designed for safety?
- ❑ How could leadership better communicate the importance and value of safety?
- ❑ How could the organization better disseminate and share safety information or lessons learned from safety events across units (i.e., become more transparent)?
- ❑ How could the organization better promote, reinforce or encourage safe practices?
- ❑ How could the organization's structure be redesigned to improve the coordination and integration of activities across divisions/departments?
- ❑ How could policies (promotion, sick leave, overtime, etc.) within the organization be changed to improve safety?
- ❑ How could leadership become more engaged with staff or more aware of safety issues (e.g., leadership "walk-arounds")?
- ❑ How could the organization improve its contingency planning for possible staff shortages, equipment failures, or budgetary restrictions?
- ❑ What tools could be developed to help supervisors identify problems with workplace design or layout?
- ❑ How could the organization change its processes for evaluating supervisors or providing feedback on supervisors' performance to improve safety?

Appendix D - HFIX Quick Reference Sheet

(Scott Shappell & Doug Weigmann, HFACS Inc.)

HFIX: For each causal/contributing factor (CCF) you identify, use the probes listed in each column to begin generating as many ideas as you can to address each problem within one of the intervention approaches listed below. The researcher will tell you when it is time to move on to the next approach.

Continue until you have explored options using all the HFIX approaches.

- **Environmental Factors**: Refers to the physical working environment in which individuals and teams perform their activities
- **Task Factors**: Refers to the physical and cognitive work activities performed by individuals and teams
- **Technological Factors**: Refers to equipment, tools, software and documents that individuals and teams use during work
- **Individual/Team Factors:** Refers to the characteristics of individuals and teams performing work related activities
- **Supervisory/Organizational Factors:** Refers to the management, guidance and oversight of individuals and teams by those in positions of authority at middle and senior leadership levels

Example questions for investigating fixes to Causal/Contributing Factors				
Environment	**Task**	**Technology**	**Individual/Team**	**Supervisory/ Organizational**
How could the lighting be changed to reduce shadows, glare, or stark lighting changes?	How can the task be restructured so that it requires less reliance on human memory (i.e., use checklists or technology that signals the next step in the task)?	How could automation help in reducing the dependency on human performance of certain tasks?	How can the method of training delivery be improved or modified to enhance its impact on an individual's knowledge and skills (e.g., use of simulation)?	How could methods be developed to improve a communication between supervisors and staff?
How could the noise level be modified or reduced to reduce fatigue, improve concentration, or enhance communication?	How could immediate feedback be integrated into the task to allow operators to know when they have done things correctly or incorrectly?	How could warnings or alarms be improved to increase operators' awareness of hazards or the presence of abnormal conditions?	How could an individual's stress and fatigue be reduced or monitored to improve safety and performance?	How could the awareness and appreciation of hazards and risk by supervisors be enhanced?
How could clutter be reduced or housekeeping be improved to make the working environment more conducive to safe and productive work?	How could errors in performing the task be reduced by having another team member check/verify important steps in the procedure?	How could controls be more easily identified and/or better designed in terms of shape, size, movement and other relevant considerations?	When individuals are working as a team, how can the responsibilities of each team member be more clearly defined?	How could the organization improve its process for recruiting and hiring people who are better qualified or more experienced?
How could the number of distractions in the environment be reduced to allow the operator to focus attention more fully on the task?	How could procedures be re-written so that they are less ambiguous or more germane to safety critical tasks operators perform?	How can tools or technologies be redesigned to enter into a "failsafe" mode when problems occur?	How could the content of training be developed or modified to improve an individual's knowledge of procedures and/or tasks	How could the organization better promote, reinforce, or encourage safe practices?

Appendix E – FACES Rubric

Criterion	Low	Medium	High
	1 2	3	4 5
Feasibility Can the change be implemented relatively easily or quickly?	The intervention does not exist today nor is it likely to become available in the near future; it is highly impractical and not suitable for your organization.	The intervention exists but is not readily available or will require modifications to better fit the context in which it is intended to be used.	The intervention is readily available and could be implemented in a relatively short period of time without much effort.
Acceptability Will those being impacted by the intervention readily accept the change?	The intervention will not be tolerated by those it impacts. People are likely to consistently resist the change and attempt to work around the change.	The intervention will be tolerated by those it impacts. There may be moderate resistance but attempts to undermine the change will not be wide spread.	The intervention will be readily accepted by those it impacts. People are likely to welcome the change and make every attempt to ensure it works.
Cost/Benefit Does the benefit of the intervention outweigh the costs?	The cost of the intervention is exorbitant relative to its minimal expected impact on safety and performance.	The intervention is moderately expensive but cost could be justified by its expected benefit. Return on investment (benefits) is relatively equal to cost.	The cost of the intervention is nominal relative the expected impact on safety and performance.
Effectiveness How effective will the intervention be at eliminating the problem or reduces its consequences?	The intervention will not directly eliminate the problem or hazard and it relies heavily on willful compliance with the change and/or requires humans to remember to perform the task correctly.	The intervention reduces the likelihood of the problem or hazard occurring but relies in part on the human memory and/or willful compliance with the change.	The intervention will very likely eliminate the problem or hazard and it does not rely on willful compliance with the change or require humans to remember to perform the task correctly.
Sustainability How well will the intervention last over time?	The impact of the intervention will diminish rapidly after it is deployed and/or will require extraordinary effort to keep it working.	The benefits of the intervention may have a tendency to slowly dissipate over time and will require moderate efforts to maintain its benefits	The impact of the intervention will persist over time with minimal efforts being required to maintain its benefits.

Intervention Idea	F easibility	A cceptability	C ost/Benefit	E ffectiveness	S ustainability	Total (add the total score of each of the components together)

Appendix F – Brainstorming Problem

One of the biggest problems we have in the world today is getting people (especially children) to wash their hands regularly, despite the scientific link between washing hands and killing germs. In your group, brainstorm ways to get children to wash their hands after going to the bathroom.

Appendix G – Osborn's Four Rules of Brainstorming Reference Sheet

While you are brainstorming within your groups please remember Osborn's four rules of brainstorming:

No criticism,
Freewheeling is welcome (the wilder the better),
Quantity is wanted,
Combination and improvement should be sought out and accomplished