Augmented Reality, Virtual Reality and their effect on learning style in the creative design process

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Abstract
Research has shown that user characteristics such as preference for using an interface can result in effective use of the interface. Research has also suggested that there is a relationship between learner preference and creativity. This study uses the VARK learning styles inventory to assess students learning style then explores how this learning preference affect the use of Augmented Reality (AR) and Virtual Reality (VR) in the creative design process.

Key words

augmented Reality, Virtual Reality, Learning styles, Design education, Creativity.

Introduction
Individuals use interfaces in different ways for different purposes. Research has shown that user characteristics such as preference for using an interface can result in effective use of the interface. Factors such as cognitive style, gender, and preference have been shown to impact creativity and the ideation process (Baer, 1997; Baer & Kaufman, 2008; Lubart, 1999; Pearsall, Ellis, & Evans, 2008; Shalley, Zhou, & Oldham, 2004; Wolfradt & Pretz, 2001). Furthermore, there is a relationship between learner preference and creativity (Atkinson, 2004; Eishani, Saa'd, & Nami, 2014; Friedel & Rudd, 2006; Kassim, 2013; Ogot & Okudan, 2007; Tsai & Shirley, 2013). The purpose of this study is to explore how user characteristics (i.e. learner preferences) affect the use of Augmented Reality (AR) and Virtual Reality (VR) in the creative design process. While VR can be interpreted as immersive three-dimensional computer-generated environments (Bryson, 1995), AR can be conceptualized as overlaying virtual objects over the physical environment (Fischer et al., 2006). Researchers have investigated how AR and VR can be used in design and design education, but there is a gap in knowledge about how these interfaces affect the cognitive process of designing.
The VARK Learning Styles inventory was used to measure learner preferences for visual, auditory, read/write, and kinaesthetic learning styles. The VARK is considered to be a valid learner preferences tool and it has been used by many researchers (Bell, Koch, & Green, 2014; Drago, & Wagner, 2004; Lau, Yuen, & Chan, 2015). It was used in this study because it focuses on kinaesthetic and visual learning styles, which relate to the characteristics of the interfaces that are investigated in this study. The rationale in this study was that learners with a preference for kinaesthetic learning will prefer to use an interface that provides more

tactility, while those who have a preference for visual learning will prefer to use an interface that provides more visual cues.

Learning styles are thought of as a user's preference for using a certain modality as a means to learn. The main hypothesis of the study stems from the fact that the learner preference correlates to the acceptance of that particular technology, thereby affecting the creative design process through intrinsic motivation (see Figure 1).

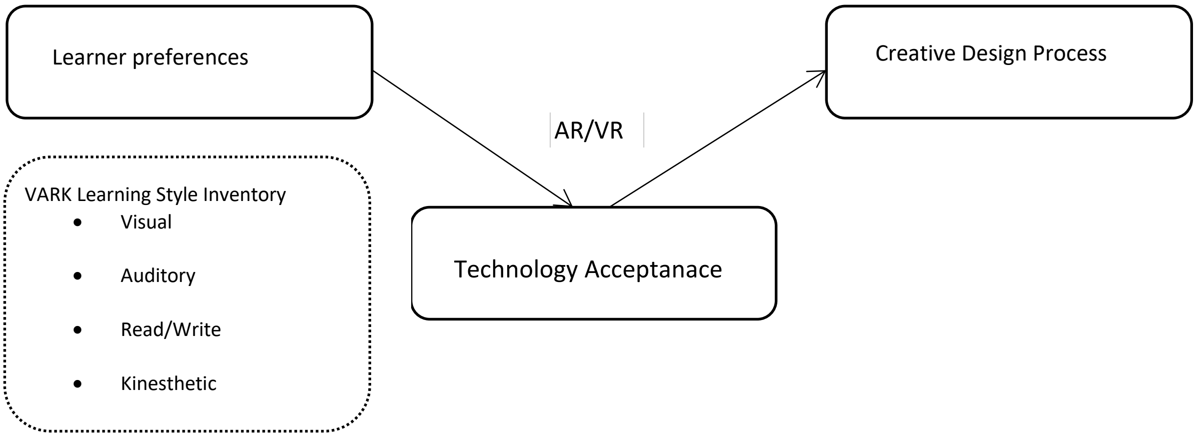


Figure 1. Effect of learner preferences on using AR and VR in the creative design process.

Virtual Reality (VR) and Augmented Reality (AR)

VR has been extensively used in educational environments. As AR technology is becoming more accessible, it is being more often adapted for mainstream use. While VR can generally be interpreted as an immersive three-dimensional computer-generated environment, AR can be thought of as overlaying of the virtual over the physical environment.

VR is a simulated three-dimensional environment which either emulates the real world or acts as an imaginary world. Even though the majority of virtual environments cater to the visual sense, virtual environments can cater to the auditory, haptic, olfactory, and even the taste sense. VR is commonly used as an entertainment, education, and research tool. It offers a wide variety of options and opportunities in conducting research, especially in human behaviour research, since virtual environments can be controlled according to the need of the researcher.

AR has been defined as a variation of VR (Azuma, 1997). While VR completely immerses the user inside a computer-generated environment where the user cannot relate to the physical environment, AR allows the overlaying of virtual elements onto the physical environment. AR can be considered a hybrid of virtual and physical environments and therefore supplements reality rather than replacing it. Given the similarities and overlapping of certain characteristics between these two interfaces (AR and VR), there is a critical need to identify advantages or disadvantages of one over the other for its use in a specific domain. AR is an interface that offers tangible interaction (Ishii, 2007) and is often referred to as tangible user interface (TUI). There for the tangible nature of AR might appeal to kinaesthetic users as compared to the visual nature of VR, which might appeal more to the visual learners.

Even though AR has existed for several decades, there is a gap in the knowledge about how human factors affect the use of AR (Huang, Alem, & Livingston, 2012). Better understanding of user experience factors in AR environments is important for a number of reasons. With the emergence of new hardware that has the capability of supporting AR applications, interest in how to use this technology efficiently has been increasing. Such studies are only currently becoming feasible because of the recent maturation of the technology. Extensive studies of this type will allow the development of specific and general design and usage guidelines for AR technology not only in design education and design practice but in other fields of study as well. Moreover, understanding human perception of AR will accelerate the introduction of such technologies into mainstream use beyond the current novelty value of AR.

Effects of User Characteristics on the Design Process

Digital interfaces affect the design process in a number of ways, such as the way the individual use it, the familiarity with the tools and the intrinsic qualities of the tool. It is important to understand how these interfaces affect the design process and thereby the people using them. The purpose of this study is to explore digital interfaces and user preferences for learning.

Research on using digital media in design education has for the most part focused on the development of the technology. Whatever user evaluation has been done has focused on technical aspects rather than using a human-centred approach (Gab bard & Swan, 2008). Nevertheless, both system and user performance measurements are important aspects for AR because the technology coordinates the physical environment and the computer-generated overlaid environment (Grier et al., 2012).

In his 10 books on architecture, Vitruvius stated that an architect should be a good writer, a skilful draftsman, versed in geometry and optics, expert at figures, acquainted with history, informed on the principles of natural and moral philosophy, somewhat of a musician, not ignorant of the law and of physics, nor of the motions, laws, and relations to each other, of the heavenly bodies (as cited in D'Souza, 2009, p. 173). Apart from these basic technical skills, an architect is assumed to have or acquire imagination and be creative and must gain artistic and intellectual abilities as well (Potur & Barkul, 2007). Isham (1997, p. 2) stated, "The ability to concisely communicate a highly complex and creative design solution has at its creative core visualization skills (internal imaging) that allow designers to mentally create, manipulate and communicate solutions effectively."

These different characteristics that make a designer may depend on the designer's innate skills and intelligences as well as the learning method. Thurstone (1938) described intelligence as a combination of factors such as associative memory, number facility, perceptual speed, reasoning, spatial visualization, verbal comprehension, and word fluency. He further identified three factors of spatial ability, mental rotation, spatial visualization, and spatial perception. D'Souza (2006) stated that designers use the seven types of intelligences which Gardener (1983) discusses – logical, kinaesthetic, spatial, interpersonal, intrapersonal, verbal, and musical intelligence – and suggested the addition of graphical, suprapersonal, assimilative, and visual intelligences to the types of intelligences so that the framework for design intelligence is more comprehensive.

According to Gardner's multiple intelligences theory, individuals have a distinctive capacity to succeed in a particular field, and the method of educating these individuals should foster these intelligences. The idea of learning styles suggests that individuals have a particular way of learning that works best for them. For example, some individuals learn more easily from visual activities and some learn more easily from hands-on activities. Educators should identify the learning style best suited for the student.

Understanding the learner preferences of the individual is important when selecting the instructional medium. In this study, emphasis is on learner preference instead of intelligences because this study focuses on the modality through which information is provided to the students (i.e., through the AR or VR interface).

Learning Styles

Researchers have attempted to identify how individuals learn and have provided a number of categorizations. The term "learning styles" was first used in an article by Thelen in 1954, and thereafter has been defined by many. Ausubel, Novak, and Hanesian (1968) defined it as "self-consistent, enduring individual differences in cognitive organization and functioning" (p. 203), while Keefe (1979) defined it as "cognitive, affective, and physiological traits that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (p. 2). A general definition of learning styles was provided by James and Gardner (1995) as the different patterns of how individuals learn.

A number of researchers have presented theoretical frameworks that explain these learning styles. Curry's (1983) onion model explores different learning style theoretical frameworks and provides four main categories: personality learning theories, information processing theories, social learning theories, and multidimensional and instructional theories.

According to the onion model, some learning theories focus on the personality of the individual (such as the Myers-Briggs indicator), information processing theories describe how individuals perceive and process learning activities. Kolb's (1984) model of information processing is an example of this type of theory. Social learning theories describe an individual's interaction with the environment. The fourth type attempts a more holistic view of learning through analysing multiple dimensions. In his multiple intelligence theory, Gardner described several dimensions of learning, such as inter personal, intra personal, visual-spatial, bodily-kinaesthetic, linguistic, and logical (Gardner, 1983).

While many of these theories propose using learning styles as a mechanism to better meld instructional modalities to cater to the individual, the rationale in identifying learning styles in this study is to understand the user preference for digital interfaces and the efficient use of that digital interface in the creative design process. Dunn (1993) stated that

> if individuals have significantly different learning styles, as they appear to have, is it not unprofessional, irresponsible, and immoral to teach all

> students the same lesson in the same way without identifying their unique strengths and then providing responsive instruction? (p. 30)

Therefore, the logical question that remains is not whether educators should instruct students in different ways but which methods are best for which students.

Learning Styles in Design Education

Learning styles that are applicable to design are defined by the way designers observe and solve design problems. Design educators have explored design students' learner preferences and styles by observing learner preferences of design students (Demirbas & Demirkan, 2003; Kvan & Jia, 2005). Newland, Powell, and Creed (1987) identified four types of design learners by using Kolb's learner styles as a starting ground. Durling, Cross, and Johnson (1996) observed cognitive styles using the Myers-Briggs type indicator (Briggs, 1976) to identify the connection between teaching and learning in design schools.

Students of different disciplines have shown preferences for a certain type of learning style. For example, using the VARK questionnaire, Lujan and DiCarlo (2006) found that medical students prefer multiple learning styles. Felder and Silverman (1988) stated that the learning styles of most engineering students are mismatched with teaching styles of most engineering professors and recommended that professors use different methods to facilitate the learner preference of the students. The learner preference of students from a certain discipline may be similar for a number of reasons, such as shared interests or similar aptitude. In design education, students tend to be more visual and to enjoy working with physical objects such as building prototypes. These preferences and aptitudes may predispose them to a certain learner preference.

Researchers have stated that the most important facet of design and design education is self-reflection, in which a designer would revisit and reflect on the design decisions that have been made (Newland, Powell, & Creed, 1987). Trial and error problem solving encourages and facilitates this type of self-reflective design ideation in enhancing the creative design process (Harnad, 2006). The fact that trial and error type of problem solving plays a major role in a design students' academic career might influence their learner preference as well.

Creativity, Motivation, and Acceptance

Motivation is generally understood as a personal drive to accomplish. Motivation can be intrinsic or extrinsic. Intrinsic motivation is defined as doing something for one's own satisfaction (Amabile & Gryskiewicz, 1987) and extrinsic motivation is defined as "the motivation to work on something primarily because it is a means to an end" (Amabile, 1987, p. 224).

Researchers have studied the connection between intrinsic motivation and creativity (Amabile, 1985; Collins & Amabile, 1999; Hennessey, & Amabile, 1998; Koestner, Ryan, Bernieri, & Holt, 1984) as well as motivation and creativity in the context of design (Casakin & Kreitler, 2010; Kreitler, & Casakin, 2009) and found that when motivation is less, creative output decreases (Collins & Amabile, 1999). Runco (2005, p. 609) stated that “creative potential is not fulfilled unless the individual is motivated to do so, and creative solutions are not found unless the individual is motivated to apply his or her skills.”

Research has shown that extrinsic motivation for using assistive technology is captured by the PU construct in the TAM (Davis, 1989; Venkatesh & Davis 2000; Venkatesh & Speier, 2000). Furthermore, Venkatesh, (2000) stated that intrinsic motivation is related to PEU. Because technology acceptance is affected by perceived ease of use and perceived ease of use is affected by intrinsic motivation, intrinsic motivation would appear to affect technology acceptance (see Figure 2).

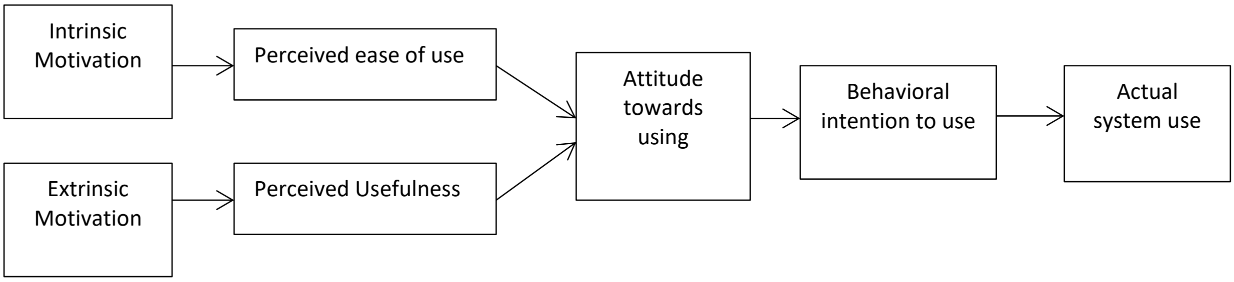


Figure 2. Effect of motivation on the technology acceptance model (TAM).

Perceived ease of use is a predictor of intrinsic motivation and intrinsic motivation enhances creativity. Through this link I examine whether perceived ease of use is related to creativity. Anasol, Ferreyra-Olivares and Alejandra (2013) proposed that the learning experience of kinaesthetic learners could be enhanced through the tangibility of user interfaces. They further stated that virtual environments can be used as extensions of traditional physical classrooms, motivating visual or aural learners. Therefore, they suggest that user preference would affect the use of VR and AR interfaces in design and thereby affect the creative design process (see Figure 3).

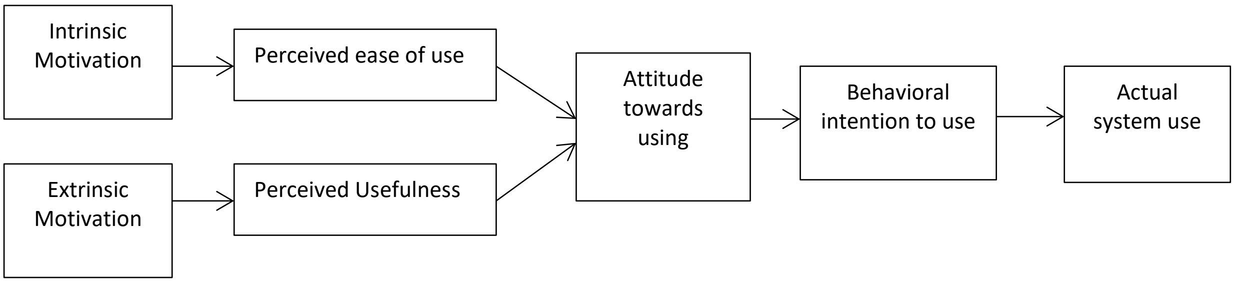


Figure 3. Effect of learner preference through digital modalities.

Measuring Learning Styles: VARK Learning Styles Inventory

The VAK (visual, auditory, kinaesthetic) and VARK (visual, aural, reading and writing, kinaesthetic) learning style inventories have been used in many studies (Bell, Koch, & Green, 2014; Drago, & Wagner, 2004; Lau, Yuen, & Chan, 2015; Marcy, 2001; Wehrwein, Lujan, & DiCarlo, 2007). Fleming (2001; Fleming & Mills, 1992) attempted to establish perceptual modes as a measurable construct through the VARK inventory, which focuses on the individual preferences of using different perceptive modalities in obtaining and retaining information efficiently.

Aural learners prefer receiving information through discussions, seminars, lectures, and conversations. Visual learners obtain information efficiently through pictures and other visual means such as charts, graphs, and other symbolic devices instead of words. Learners who prefer obtaining information through text are identified as readers/writers. These learners prefer textbooks, taking notes, readings, and printed handouts. Kinaesthetic learners prefer to learn through practical examples which also may involve other perceptual modes. **They** prefer practical examples, hands-on approaches in problem solving, and trial and error solutions to problems. Those who prefer obtaining information through multiple sources are identified as multi-modal. The VARK Learning styles inventory has gained immense popularity because of its face validity and simplicity, which Leite, Svinicki, and Shi (2010) confirmed using factor analysis to compare four multitrait-multimethod models to evaluate the dimensions in the VARK. They stated that the estimated reliability coefficients were adequate.

Method

This study employs a quantitative research design using analysis of subjective survey data. The study explores the research questions mainly by closely examining the responses of a small number of participants. The independent variable (i.e., the interaction environment) had two levels: AR environment and VR environment. The design of the study included learner preference as a moderating variable and the dependent variable of technology acceptance.

This research seeks to answer the following questions:

How does type of user interface (AR/VR) and learner preference affect the creative design process?

RQ1.1: How does interface type affect technology acceptance?

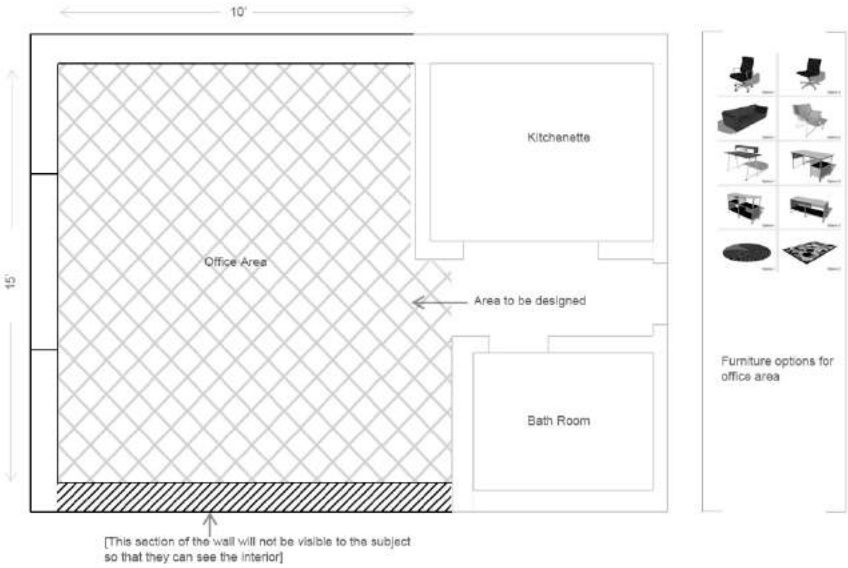
RQ1.2: How does learner preference interact with media type to affect technology acceptance?

Hypotheses for RQ1.1-1.2

- H1: The type of user interface used in design problem solving affects the perceived ease of use (PEU) of the user interface.
- H2: The type of user interface used in design problem solving affects the perceived usefulness (PU) of the user interface.
- H3: The type of user interface used in design problem solving affects the behavioural intention to use (IU).
- H4: The learner preference of the user moderates the PEU of the user interface.
- H5: The learner preference of the user moderates the PU of the user interface.

- H6: The learner preference of the user moderates the IU of the user interface.

Two design problem-solving interfaces were employed: an AR interface and a VR interface.



Both interfaces used a tabletop webcam and fiducial marker-based system. Thirty volunteers participated in the study. After approval by the institutional review board, the participants were chosen by purposeful sampling (Gall, Gall, & Borg, 2007). After announcing the research opportunity to design students (juniors and seniors) at a Midwestern university in the US, students were offered a chance to participate in the study. They were informed that there would be monetary incentive of $25 for participating. Volunteers were provided with copies of the informed consent form. The participants were then randomly assigned to one of the two interaction environments, AR/VR. Table 1 shows the demographic information of the participants.

Table 1. *Demographics in the Two Groups*

	Gender		Age		Academic	
	M	F	18-25	30-35	Senior	Junior
AR	0	15	15	0	6	9
VR	1	14	14	1	8	7

Figure 4. Floor plan of the office space.

The design problem was formulated in consideration of two main factors. The first was to provide a simple problem which would encourage the participants to focus on object manipulation, spatial and logical iterations, context, and user-behaviour issues, while also keeping in mind visual appeal, composition, environmental considerations, and ergonomic factors. The second consideration was previous studies that were conducted for a similar purpose.

All 30 participants responded to two questionnaires based on the technology acceptance model (post-test) and the VARK learning styles inventory (pre-test) to better understand how the interface affects the design process and human perception. In this study, the task was to arrange furniture within a small (15’ X 10’) office space (Figure 4). The floor plan was rectangular and had openings for windows and doors.

There were three main differences in the AR and VR environments. Firstly, in the VR environment a regular PC mouse was used as the interaction device and the manipulation was accomplished by dragging along the axis, while in the AR environment the fiducial markers were used in order to move and rotate the objects. Secondly, in the VR environment the screen transparency was set to 0 and in the AR environment it was set to 100. Thirdly, while in the AR environment each piece of furniture was assigned to a single marker, but in the VR environment all markers were printed on a single sheet, then moved and rotated using the PC mouse. The AR working environment is pictured in Figure 5 and the VR working environment is pictured in Figure 6.

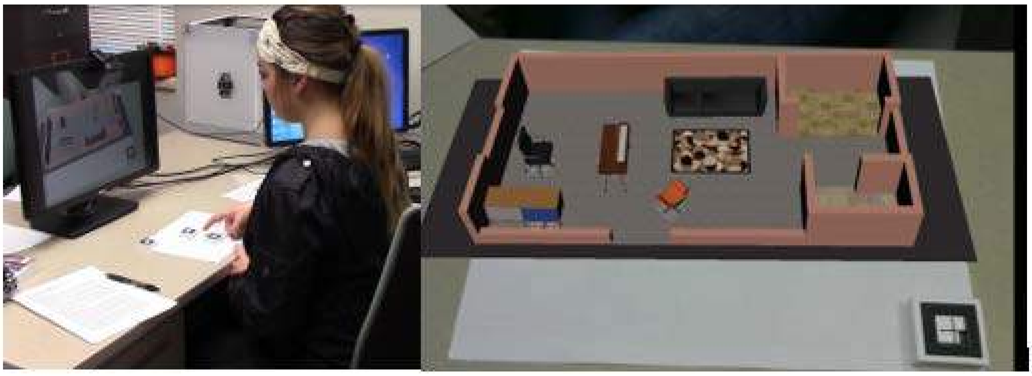


Figure 5. The augmented reality working environment.

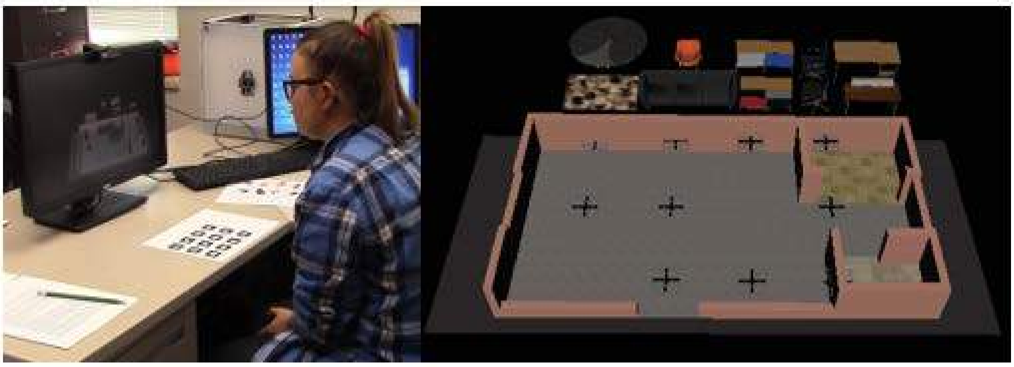


Figure 6. The virtual reality working environment.

Analysis and Discussion

Previous studies have shown that creativity is affected by intrinsic motivation. Furthermore, intrinsic motivation has been shown to be driven by the Perceived Ease of Use (PEU) of an assistive technology. PEU is one of the factors emphasized in the Technology Acceptance Model (TAM). In order to determine how the interface type affects learner preference, Perceived Ease of Use (PEU), Perceived Usefulness (PU), and Intention to Use (IU) were compared between the two interface types for two learning styles; visual and kinaesthetic learning styles.

Multivariate statistical software (SPSS version 20) was used to obtain descriptive statistics and to perform statistical analyses. A series of statistical tests were performed to test the research hypotheses. A one-way analysis of variance (ANOVA) was performed to compare the dependent variables (PU, PEU, and IU) between the two interface types. A two-way ANOVA was performed to explain the interaction between interface type and learner preference. To assess the relationship between PU and IU as well as PEU and IU, bivariate correlation coefficients (Pearson's r) were computed.

Reliability and Validity of the Instrument

The TAM instrument was adopted from an established TAM scale. The tool measures the subjective perceptions of technology use and has been previously validated in a number of studies (Davis, 1989; Davis, 1993; Dishaw & Strong, 1999; Igbaria, 1993; Igbaria, Schiffman, & Weickowski, 1994). Internal consistency of the measures in the TAM instrument was assessed by Cronbach's alpha (α) computed using SPSS. Cronbach's alpha ranges between 1 and 0, and internal consistency is considered greater as the value approaches 1. In the instrument used in this study, the PEU subscale consisted of nine items ($\alpha = .813$), and the PU subscale consisted of 5 items ($\alpha = .58$). In order to improve the α level for the PU subscale, one item was removed, which improved the Cronbach's α value to 0.65. DeVellis (1991) stated that an α value of 0.60 to 0.65 is undesirable but acceptable. The IU subscale consisted of two items ($\alpha = .79$).

The VARK questionnaire (Fleming & Mills, 1992) is an established learning style evaluation tool and was used without any modification, so checking the reliability or validity of the tool was not necessary.

Comparison of the Dependent Variables (PU, PEU and IU) between the Interface Types

A one-way ANOVA analysed the difference between interface type and the dependent variables. Table 2 shows the descriptive statistics for PEU, IU, and PU by interface type. ANOVA results for PU, IU and PEU are presented Table 3.

Table 2. *Descriptive Statistics for the Virtual and Augmented Reality Interfaces*

Dependent Variable	Independent Variable	Mean	SD
Perceived Usefulness (PU)	VR	4.83	1.08
	AR	5.90	0.60
Behavioural Intention to Use (IU)	VR	4.70	1.33
	AR	6.20	0.80
Perceived Ease of Use (PEU)	VR	5.52	0.95
	AR	6.23	0.26

Note: N = 15 *(In each group)*

Table 3. ANOVA Summary Table for Interface Type

Dependent Variable	Source	SS	df	MS	F	p
Perceived Usefulness	Between Groups	8.533	1	8.533	11.213	.002
	Within Groups	21.308	28	0.761		
	Total	29.842	29			
Behavioural Intention to Use	Between Groups	16.875	1	16.875	13.979	.001
	Within Groups	33.800	28	1.207		
	Total	50.675	29			
Perceived Ease of Use	Between Groups	3.793	1	3.793	7.804	.009
	Within Groups	13.608	28	0.486		
	Total	17.401	29			

The difference between the two interface types was significant for all three dependent variables: PU, $F(1,28) = 11.21$, $p = .002$); IU, $F(1,28) = 13.979$, $p = .001$); and PEU, $F(1,28) = 7.804$, $p = .009$). All three dependent variable means were significantly higher in the AR interface type, PU: $M = 5.90$, $SD = 0.60$; PEU: $M = 6.23$, $SD = 0.26$; and IU: $M = 6.20$, $SD = 0.80$, compared to the VR interface type, PU: $M = 4.83$, $SD = 1.08$; PEU: $M = 5.52$, $SD = .95$; and IU: $M = 4.70$, $SD = 1.33$.

Comparison of the Dependent Variables between Interface Type and Learner preference

In order to understand the interaction between interface type (independent variable) and learner preference (moderating variable) on the dependent variables (PU, PEU and IU), a two-way ANOVA was performed for each of the dependent variables. See Table 4 & 5.

Table 4. Descriptive Statistics for Perceived Usefulness

Interface Type	Learner Preference	Mean	Std. Deviation	N
VR	Visual	4.25	.50000	3
	Aural	6.08	.52042	3
	Read/Write	4.81	.42696	4
	Kinaesthetic	4.94	1.06800	4
	Multimodal	2.50	.	1
AR	Visual	6.15	.54772	5
	Aural	5.67	.14434	3
	Read/Write	5.25	.00000	3
	Kinaesthetic	6.42	.80364	3
	Multimodal	5.75	.	1

Table 5. Two-Way ANOVA Summary Table for the Effect of Learner Preference and Interface Type on Perceived Usefulness

Source	SS	df	MS	F	p
Interface Type	10.127	1	10.127	26.849	.000
Learner preference	6.249	4	1.562	4.142	.013
Interaction	7.956	4	1.989	5.273	.005
Error	7.544	20	.377		
Total	893.875	30			

Note. R^2 = .747 and adjusted R^2 = .633

The effect of the interaction between the interface type and learning style on the PU is significant, $F(4,20) = 5.273$, $p < .005$. The main effect for interface type on PU is also significant, $F(1,20) = 26.85$, $p < .001$. Furthermore, the main effect of learner preference on PU is significant, $F(4,20) = 4.142$, $p < .013$.

Table 6. Differences in Perceived Usefulness between Augmented and Virtual Reality Interface by Learner preference

Learner Preference	Mean Difference	SE	*p*

Visual	-1.900*	.449	.000
Aural	.417	.501	.416
Read/Write	-.437	.469	.362
Kinaesthetic	-1.479*	.469	.005
Multimodal	-3.250*	.869	.001

**p* < .01

The pairwise comparisons suggested that the mean PU score was significantly higher in the AR environment than the VR environment for kinaesthetic learners. Furthermore, the mean PU was significantly higher in the AR environment than the VR environment for visual learners. For PEU and IU, the interaction between interface type and learner preference was not significant (p = 0.092 and 0.074 for PEU and IU, respectively).

Because the multimodal learner category only had two participants (one for each interface type), the two participants were removed from the data set and the two-way ANOVA was rerun to observe any difference in the results. Removing these two participants made no difference in the results obtained for the interaction between learner style and interface type on PU, PEU, or IU.

Relationships between Perceived Usefulness and Behavioural Intention to Use as well as Perceived Ease of Use and Behavioural Intention to Use

To investigate the relationship of PEU and PU on the IU as suggested by the TAM, bivariate correlations (Pearson's *r*) were calculated. As expected and predicted by the TAM, all PU, PEU, and IU were positively but not strongly correlated (see Table 7).

Table 7. Correlations among Variables

		Perceived Usefulness(PU)	Behavioural Intention to Use(IU)
Behavioural Intention to Use (IU)	Pearson's r	.689**	
	Sig. (2-tailed)	.000	
Perceived Ease of Use (PEU)	Pearson's r	.480**	.589**
	Sig. (2-tailed)	.007	.001

Note: N = 30 ** *p* < .001

Summary of Findings

In this study, two research questions were investigated: How does interface type affect technology acceptance? And how does learner preference interact with the interface type to affect technology acceptance? Hypotheses H1 through H6 were tested.

> *H1: The type of user interface used in design problem solving affects the Perceived Ease of Use (PEU) of the user interface.*
>
> *H2: The type of user interface used in design problem solving affects the Perceived Usefulness (PU) of the user interface.*
>
> *H3: The type of user interface used in design problem solving affects the Intention to Use (IU).*

According to results of the ANOVA, the difference between the two interface types was statistically significant for all three dependent variables, PU, IU, and PEU. All three variables had a higher value in the AR interface. The conclusion is that participants found AR to be easier to use and more useful and were more inclined to use it in the future than VR. Null hypotheses for H1-H3 were rejected.

> *H4: The learner preference of the user moderates the PEU of the user interface.*
>
> *H5: The learner preference of the user moderates the PU of the user interface.*
>
> *H6: The learner preference of the user moderates the IU of the user interface.*

According to the results of the two-way ANOVA, the interaction between the interface type and learner preference was significant for PU. As expected, the PU score was significantly higher in the AR environment than the VR environment for kinaesthetic learners. Contrary to expectations, the mean PU was also significantly higher in the AR environment than the VR environment for visual learners. The null hypothesis for H5 was rejected.

Research has shown that extrinsic motivation for using assistive technology is captured by the PU construct in the TAM (Davis, 1989; Venkatesh & Davis 2000; Venkatesh & Speier, 2000). Furthermore, Venkatesh, (2000) stated that intrinsic motivation is related to PEU.

PEU is a measurement of intrinsic motivation that enhances the creative design process. PU is a means of measuring extrinsic motivation. For PEU and IU, the interaction between interface type and learner preference was not significant. From these results the conclusion cannot be made that learner preference moderates the creative design process in a given interface type. Therefore, the null hypotheses for H4 and H6 were not rejected.

As expected and as proposed in the TAM, this study found positive correlations between IU and PU as well as IU and PEU. This result validates previous results and the methodology used in this study.

Participants rated PU, PEU, and IU higher for the AR interface. The conclusion is that kinaesthetic and visual learners found the AR environment more useful than the VR environment.

Conclusions

The main research question of the study focused on a relationship between user preference and creativity in the design process when using Augmented Reality (AR) and Virtual Reality (VR). The AR environment was operationalized as an interface that offered tangible interaction, as compared to VR which functioned within the Windows, Icons, Menus and Pointers (WIMP) paradigm.

This study provided information on how user preference affects the use of different interfaces. The results suggest that participants perceived AR to be easier to use, more useful and were more inclined to use it in the future than VR. As expected, kinaesthetic learners found the AR environment more useful than the VR environment. However, contrary to expectations, visual learners found the AR environment more useful than the VR environment. The AR interface used in this study was similar to the VR interface in every way except for the method of interaction and interface transparency. However, the interaction in the AR interface was achieved by using a fiducial marker, which may not be the ideal method of interaction for AR. This might be a factor to explain the unexpected result that visual learners found AR to be more useful than VR. True tangible interaction for AR may be achieved by using devices such as a leap motion controller that provide tangible interaction with virtual objects. From these results, the conclusion cannot be made that learner preference moderates the creative design process in a given interface type.

This study has theoretical, methodological, and practical implications. The implications of the study provide designers and design educators with insights into the selection of different types of interfaces that affect the creative design process. Furthermore, the results of the study offer suggestions to developers of instructional and educational media and materials to create content for different types of interfaces. The theoretical framework established the connection between Perceived Ease of Use (PEU) and creativity through intrinsic motivation. While learner preference did not significantly affect creativity, technology acceptance was higher for the AR environment, and learner preference affected Perceived Usefulness (PU). These theoretical implications can contribute practical insights to multiple domains on using different interface types in the design process.

From a practical standpoint, the findings of this study contribute to helping designers and design educators use interfaces such as AR and VR in the design process. The results of the current study show how learner preference moderates user acceptance of different interface types and may affect the creative design process. Even though there was no relationship between creativity in the design process and learner preference under the AR and VR interfaces, the learners' PU, PEU, and Behavioural Intention to Use (IU) were all significantly higher in the AR interface than in the VR interface. This finding is consistent with previous findings on AR and user acceptance (Chandrasekera, Yoon & Balakrishnan, 2012). These theoretical implications can contribute practical insights to multiple domains on using different interface types in the design process.

Limitations

The current study was designed with numerous methods of limiting errors and enhancing the validity of the research protocol in investigating how user learner preferences affect the use of Augmented Reality (AR) and Virtual Reality (VR) in the creative design process. However, as in all research of an exploratory nature, there are some unavoidable limitations.

First, the participants were college students in a design program at one Midwestern college in the United States. Most of the students were living in the same region. The study focused on design and the design process, and the students that were recruited were design students who were in their junior and senior years of study. Even though the participants were randomly assigned to the AR or VR group, six seniors and nine juniors were in the AR group, while eight seniors and seven juniors were in the VR group. This unequal distribution might have affected the results of the study because the senior students are more experienced in the design process than the junior students. Another major limitation was the unequal gender distribution: 29 out of 30 participants were female.

The second limitation was the small number of participants recruited in the study. One of the reasons for the small sample size was obtaining participants for the research study. The entire data collection took place from December, 2014 to April, 2015. Although an incentive was offered, the need to dedicate some time out of their busy and limited schedules contributed to the students' decision to refrain from participating in the study.

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