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# An Investigation of Look Cues and Pick Cues for Guidance in Dense Operating Environments

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**Abstract**

Interaction cues, which inform users about potential actions to take, are common to many types of extended reality applications. While numerous studies have compared individual interaction cues, few studies have investigated combinations of interaction cues for complex tasks, particularly ones involving high counts of similar actions. We present a within-subject study ($n=48$) investigating the effects of interaction cue combinations for guiding users through in-cockpit procedures for a UH-60 Black Hawk helicopter. The results of our study indicate significant effects for different interaction cue combinations for perceived mental effort and discomfort. Furthermore, the completion time results in our study contradict previous results pertaining to the effectiveness of specific interaction cues, which we believe are due to the context and complexity of the real-world application underlying our study. These results imply that Look Arrow and Pick Arrow are the optimal interaction cue combination for scenarios that involve dense operating environments.

**Keywords**

virtual reality, interaction cues

## Introduction

Augmented reality (AR) and virtual reality (VR) applications incorporate features that inform users to perform specific interactions at any given time. For example, many AR applications provide guidance for completing real-world tasks, such as inspection and assembly tasks (Gattullo et al., 2020). Similarly, VR experiences also prompt users to perform certain actions, such as looking at points of interest (Rothe et al., 2019) or traveling to key locations within the environment (Hu et al., 2020). In recent work, Dillman et al. (2018) has coined these types of virtual instructions and guidance as “interaction cues.”

While the term is recent, interaction cues have been around nearly as long as the concepts of AR and VR. In recent years, researchers have begun comparing these interaction cues for different tasks including: looking (Bork et al., 2018), traveling (Kumaran et al., 2023), picking objects (Lange et al., 2020), manipulating objects (Henderson & Feiner, 2011), performing gestures (Lee et al., 2019), and social interactions (Kim et al., 2019). Researchers have also explored different modalities of interaction cues such as visual (Gattullo et al., 2020), auditory (Lokki & Grohn, 2005), tactile (Marquardt et al., 2020), and even olfactory cues (Howell et al., 2016).

Even though the number of studies investigating interaction cues has dramatically increased in recent years, the majority of these studies have focused on comparing individual cues. On the other hand, only a few studies have investigated sequential interaction cues, in which one interaction cue follows another (Seeliger et al., 2021). This distinction is important as recent research indicates that sequential combinations of interaction cues attract significantly more eye fixations than non-sequential cues (Seeliger et al., 2021).

In this paper, we present an empirical study investigating sequential combinations of cues, specifically look and pick cues. Our decision to investigate look and pick cues was motivated by our development of an AR/VR application for guiding co-pilots through in-cockpit procedures for a Black Hawk UH-60 helicopter (UH meaning Utility Helicopter), such as those used by the U.S. Coast Guard. Conventionally,

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these co-pilots rely on handheld paper or electronic checklists to complete hundreds of steps required for these preflight procedures. By using look and pick cues, the instructions are now appropriately co-located in the environment to guide users to points of interest. This key feature of our application is capable of guiding co-pilots through hundreds of steps without the need to refer to auxiliary instructions of checklists. However, through demonstrations of our system to stakeholders, we determined that it would be best to investigate various look cues and pick cues and their sequential combinations. Additionally, we decided to investigate and compare simulated AR and standard VR field of view (FOV), as our application is capable of running as an AR guidance application within a real UH-60 cockpit or as a VR training application with a virtual UH-60 cockpit.

Therefore, we conducted a $2 \times 3 \times 3$ (FOV × Look Cue × Pick Cue) within-subject study to investigate potential sequential effects among the cues and to identify the best set of look and pick cues for our UH-60 guidance application. For FOV, we investigate a simulated AR FOV ($43^o \times 29^o$) and a VR FOV ($106^o \times 96^o$). For Look Cue, we investigated the Attention Funnel (Biocca et al., 2006), EyeSee360 (Gruenefeld et al., 2017), and Look Arrow (Harada and Ohyama, 2022) techniques. For Pick Cue, we investigated the Ghost Hand (Muresan et al., 2023), Pick Arrow (Lange et al., 2020), and Target Outline (Schwerdtfeger & Klinker, 2008) techniques.

The results of our study indicate that cue sequences have significant interaction effects and developers should not pair any look cue and pick cue together without considering how they affect one another. Furthermore, our results indicate that a pick cue for a preceding task can affect the perception and execution of the following look cue and task, respectively. Our results also indicate that simple cues, such as look and pick arrows, are more effective, require less effort, and induce less discomfort than complex visualization cues, such as EyeSee360.

## Related Work

Interaction cues have been used to guide users during several types of tasks. Dillman referred to these different types of tasks as the purpose of each interaction cue and identified three purposes within their framework for visual interaction cues: (1) discover, (2) look, and (3) go (Dillman et al., 2018). Hu identified four additional interaction cue purposes in their work, (4) pick, (5) manipulate, (6) gesture, and (7) speak, and later demonstrated that the purpose of a cue has significant effects on user performance (Hu et al., 2020). Hence, we have decided to focus on related work that investigated and compared interaction cues for tasks similar to those of a UH-60 preflight procedure, namely look and pick purposes.

In our work, we denote interaction cues that aid in looking as look cues. In our review of the literature, the vast majority of the surveyed studies investigated at least one or more look cues (24 studies in total). Of those, 17 studies investigated only look cues. As a result, a wide variety of look cues have been investigated, including within-view arrows (Wallgrün, 2020 ), the latitudinal and longitudinal EyeSee360 visualization (Gruenefeld et al., 2017), attention funnels that arc from the center of the user's FOV to the target object (Biocca et al., 2006), arrows flying from the center of the user's FOV to the target (Gruenefeld et al., 2018), 3D halos about the targets that extend within the user's FOV (Gruenefeld et al., 2017), objects within the user's periphery that indicate the direction of the target (Bork et al., 2018), radar and map visualizations that provide top-down views (Jung et al., 2018) wedges that extend from the center of the user's FOV to the target (Yu et al., 2019), and several other unique look cues. Figure 1A highlights the look cues we employed in our study.

In addition to look cues, we investigate interaction cues that aid in selection, which we denote as pick cues. Of the previously mentioned 24 studies, only 13 studies have investigated 1 or more pick cues, of which only 6 studies have investigated only pick cues. Therefore, a smaller set of pick cues have been investigated, including world-fixed arrows pointing at targets (Lange et al., 2020), effects highlighting targets in the form of distinguishing colors (E. Laviola et al., 2023), bounding volumes (Biocca et al., 2006; Seeliger et al., 2021), and outlines (Schwerdtfeger et al., 2011; Schwerdtfeger & Klinker, 2008), lines connecting targets (Liu et al., 2021), and other unique pick cues. Most recently, Muresan had virtual reality (VR) experts qualitatively compare several interaction cues, including pick cues, and they recommended that semi-transparent "ghost" hands should be used to direct the user's attention to targets (Muresan et al., 2023). While prior studies have employed ghost hands as pick cues within their applications, there have not been many empirical comparisons of ghost hands to other pick cues (Hu et al., 2020). Figure 1B highlights the pick cues we employed in our study.

## Apparatus

Our UH-60 rescue helicopter virtual environment was developed as a fully interactive cockpit in which users can press buttons, turn knobs, and view displays. All of the buttons within the cockpit can be pressed and provide both audio and haptic feedback to inform the user when a button has been pressed. This virtual environment was developed using Unity 2018.3.18f1 and the SteamVR plugin to interface with most consumer VR systems. For our study, we chose to use the Meta Quest Pro as the VR system, similar to a prior study conducted by Renner and Pfeiffer (2017). The Quest Pro provides inside-out tracking with two handheld controllers, a resolution of $1{,}800 \times 1{,}920$ per eye, a refresh rate of 90 Hz, and an FOV of $106^o \times 96^o$.

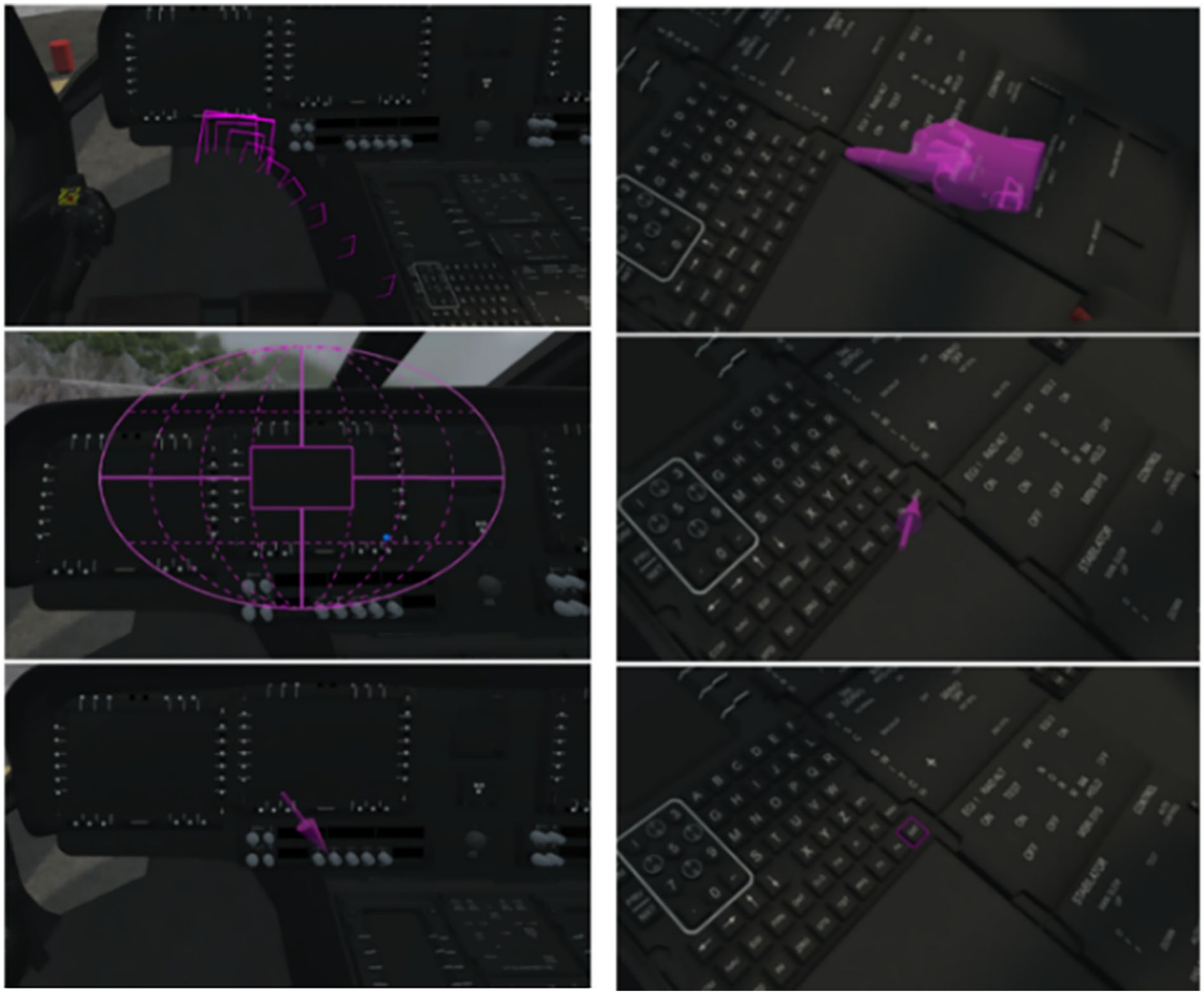

**Figure 1.** (A) The look cues used in our study (left). The Attention Funnel (Top), EyeSee360 (Middle), and Look Arrow (Bottom). (B) The pick cues used in our study (right). The Ghost Hand cue (Top), Pick Arrow cue (Middle), and Target Outline cue (Bottom).

## Experiment

We conducted a $2 \times 3 \times 3$ (FOV × Look Cue × Pick Cue) within-subject study to investigate potential sequential effects among the cues and to identify the best set of look and pick cues for our UH-60 preflight guidance applications As mentioned in the introduction, the motivation for this research was to determine the best set of interaction cues to use for guiding co-pilots through the preflight procedure of a UH-60 rescue helicopter via simulated AR (or VR for training purposes), as they conventionally use paper or electronic checklists known as "kneeboards" due to pilots placing them on their knees (Bridgeman et al., 2019). Preflight procedures often consist of hundreds of steps that involve pressing buttons and keys within the cockpit while confirming the settings of the helicopter and flight plan through multi-function displays (MFDs) and control display units (CDUs).

In order to avoid learning effects and to yield a manageable study design, we created 18 unique but similar procedures consisting of 20 steps each, with each step requiring the participant to press a button on either an MFD, CDU, or input keyboard. These 18 unique procedures facilitated our $2 \times 3 \times 3$ within-subject design and 18 conditions. We also ensured to counterbalance our conditions between subjects. To reduce the likelihood of the procedures being a confounding variable, we conducted one-way ANOVAs Procedure) on the Euclidean distances and visual angles (from a seated co-pilot position) between each button. We found no significant effect of procedure on the distances ($F_{17,324} = 0.039$, $p = 1.000$, $\eta^2 = 0.002$) or on the angles, ($F_{17,324} = 0.006$, $p = 1.000$, $\eta^2 = 0.000$). Since the procedures were found to be not significantly different, we maintained the same ordering of our 18 procedures between subjects.

## Procedure

Our experimental procedure was approved by our university's institutional review board (IRB). Recruited participants were asked to review an informed consent and eligibility document alongside providing demographics such as age and gender. Once participants reviewed and verified their eligibility, participants were asked to schedule a day and time in which they would be available to participate in the study.

Upon arrival, participants were introduced to the Meta Quest Pro, the VR system used to administer the study. We informed participants on how to adjust the head strap and lenses to comfortably wear the headset. Once participants were familiarized with the device, we then informed participants on the task they would be partaking in and how to complete the task. We explained to participants that the study is comprised of 18 procedures. Each procedure is comprised of pressing a series of 20-buttons within the cockpit. To press a button, participants would reach out toward the button as they would in real life. As their virtual hand approaches the button, it would re-pose itself to a pointing/pressing gesture so that the virtual index finger to press the button. Participants knew if they successfully pressed a button based on audible feedback via a button click sound and haptic feedback through their controller. To know which button they needed to press during the procedure, we informed participants that they will need to utilize the look and pick cues to determine which button to press. Participants were allowed to press buttons with either their left or right hand.

After explaining this process, participants were immersed into the 18 procedures. After each procedure, participants rated their discomfort on a 0 to 10-point scale adapted from Fernandes and Feiner (2016) and their mental effort on a 1- to 9-point scale adapted by Paas & Van Merriënboer (1993) in VR. Once a participant successfully completed 9 of the 18 procedures, they given a 1-min break out of VR to prevent cybersickness or fatigue. During this break, participants were administered a survey in which they ranked each look cue and pick cue. After completion of the survey and break, participants would complete the remaining nine procedures. For each condition in our study, we applied a Latin Square design to ensure conditions were counterbalanced. Total time was recorded for each trial and is the amount of time between the completion of the first step of a procedure and the completion of the last step in a procedure.

After completing all 18 procedures, participants were administered a free-response survey in which they ranked each look cue and pick cue again and then filled out open-ended questions regarding their experience, such as what they liked, what they did not like, and how they would improve the experience. The overall time required to complete the study was approximately 60 min, and participants were compensated $20 USD via an Amazon e-gift card.

## Results

In regard to Total Procedure Time, our RM-ANOVA yielded significant main effects for FOV ($F_{1,47}=6.24$, $p=.01$, $\eta^2=0.117$), look cues ($F_{2,94}=8.96$, $p\leq .001$, $\eta^2=0.16$), and pick cues ($F_{1.71,80.60}=4.77$, $p=.009$, $\eta^2=0.092$). Our post-hoc tests revealed that our simulated AR FOV conditions led to higher completion times. We also learned that in comparison to Look Arrow and Attention Funnel, conditions with EyeSee360 resulted in significantly higher completion times. Lastly, we learned that Target Outline was significantly slower than Pick Arrow.

In our analysis of Operate Error, we found a significant interaction effect between FOV and look cues across our conditions, $F_{2,94}=3.45$, $p=.03$, $\eta^2=0.068$. There also was a significant interaction effect between FOV and pick cues, $F_{2,94}=3.03$, $p=.04$, $\eta^2=0.061$. Lastly, we also found significance between look cues and Pick cues, $F_{2,94}=2.75$, $p=.03$, $\eta^2=0.055$. The results regarding mean number of errors by condition is summarized by Figure 2.

For our Mental Effort scores, which were reported by participants on the single question 1- to 9-point Paas Scale (Paas & Van Merriënboer, 1993), we found significant main effects across FOV ($F_{1,47}=4.65$, $p=.03$, $\eta^2=0.09$), look cues ($F_{2,94}=20.30$, $p<.001$, $\eta^2=0.302$), and pick cues ($F_{1.74,81.81}=10.85$, $p<.001$, $\eta^2=0.188$). Finally, our results also revealed significant interaction effects between Look Cues and Pick Cues $F_{4,188}=3.07$, $p=.016$, $\eta^2=0.061$.

Lastly, our RM-ANOVA revealed significant main effects with regard to perceived discomfort for look cues, $F_{2,94}=5.46$, $p<.01$, $\eta^2=0.104$, and pick cues, $F_{2,94}=3.77$, $p=.02$, $\eta^2=0.074$. Our post-hoc results for Look Cues revealed that EyeSee360 was significantly more discomforting to users than Attention Funnel, $t_{47}=-3.26$, $p<.01$. When compared to Look Arrow, EyeSee360 was also seen as more discomforting, but not significant, $t_{47}=-2.11$, $p=.104$. For pick cues, the Ghost Hand was found to be significantly more discomforting than the Pick Arrow, $t_{47}=-2.57$, $p=.03$. Target Outline was also perceived to be more discomforting than Pick Arrow, but was not significant, $t_{47}=-2.13$, $p=.1$

## Discussion

### *Effects of Different Look Cues*

As highlighted in our results, the type of look cue employed can have significant effects on both participant performance and perception. Notably, of our three employed look cues, we learned that participants using EyeSee360 were prone to longer procedure completion times, higher mental effort, and increased discomfort. We attribute EyeSee360′s effects to the context we employed the technique into. Our in-cockpit procedure task consists of a high volume of target button

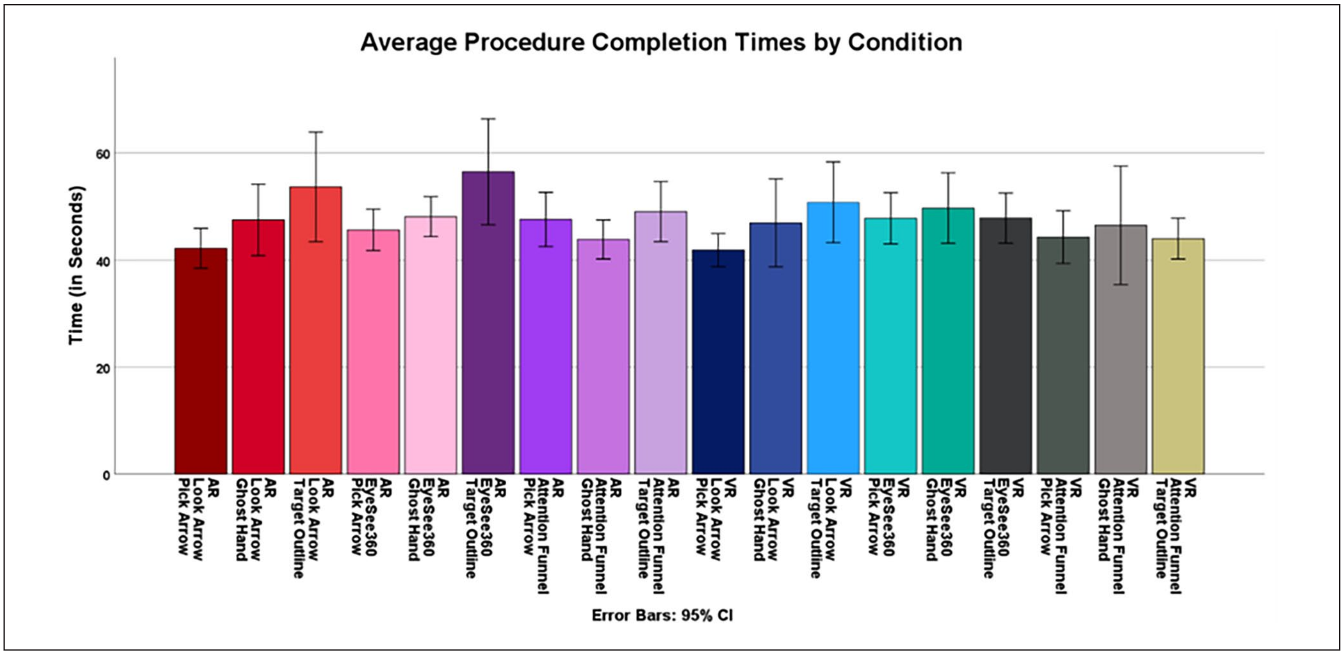


**Figure 2.** Mean completion time across our 18 conditions.

candidates that are densely co-located. Furthermore, all of the button press interactions are within a narrow field of regard (FOR; Bowman & McMahan, 2007; J. J. LaViola et al., 2017) that is consolidated to only the front hemisphere of the user.

Previous work has highlighted EyeSee360 as a unique technique that grants users the ability to locate target objects within virtual environments, particularly tasks that fully leverage a user's 360º space (Gruenefeld, 2019; Gruenefeld et al., 2017, 2018). This ability to augment a user's peripheral view is particularly useful in tasks where the target object or interactable is located outside of the user's direct field of view (Gruenefeld et al., 2017).

With the grid-like interface, combined with multiple target candidates in our study, our study revealed key limitations of EyeSee360. First, in a procedural task in which there are multiple, co-located target candidates, EyeSee360, by design, occludes much of the environment making it difficult to utilize the cue to locate the exact target candidate. One participant noted that "[EyeSee360 was] very disorienting." Another participant reported "[Having EyeSee360] move with you while I was trying to focus on buttons was somewhat difficult." Another limitation is initial perceived usability. Compared to Attention Funnel and Look Arrow, EyeSee360 is more visually complicated and is unfamiliar to users. In reflection of their time with EyeSee360, one participant described the look cue as being "difficult to understand at first" with another participant emphasizing that "[EyeSee360] was confusing."

Based on our results and participant feedback, our main takeaway is that look cues cannot be broadly applied across all contexts. For our context, a procedural task consisting of multiple interactions, benefits from look cues that are intuitive and not visually obtrusive outperform. Given our participants' lack of experience with piloting helicopters, EyeSee360 introduced a learning curve in addition to familiarizing themselves with the helicopter cockpit. Our findings suggest a look cue that is minimalist in presentation and familiar, such as Look Arrow, is best for contexts involving a high density, and volume of interaction candidates.

## *Effects of Different Pick Cues*

The type of pick cue employed can significantly affect a user's performance and perception of success in a task. Our results highlighted that Pick Arrow yielded significantly faster completion times than Target Outline. Pick Arrow also did not yield increased mental effort scores when directly compared to the Ghost Hand.

We believe a cue's performance can be attributed to how overt the cues were in presentation and how unambiguous the cues were. The Ghost Hand pick technique is very overt in presentation, but to participants, it was often confusing as the hand motioned back, and forth on the button to emulate pressing. One participant described "[not liking] the hand pointing at the button because [they] couldn't tell which one it was pointing at right away." Another participant also shared that the Ghost Hand "seems like it [was] pointing to another button. . .[as] the buttons are close together."

The Target Outline pick cue was not as overt as the Ghost Hand or Pick Arrow, but it did afford our participants a distinct view of the target button. However, as our results highlight, Target Outline yielded significantly slower completion times. This result can be attributed to how well the Target Outline blends into the environment. Though being colored magenta, the outline shape forms to the target, especially when compared to Pick Arrow and Ghost Hand. One participant made the recommendation to "change the interface of [Target Outline] to make it have the button glowing too as it would make the button easier to identify." Along the same vein, another participant wanted to make the magenta "even brighter to make it even easier to see."

With our results alongside our participants' feedback, tasks comprising of a high density and volume of targets require pick cues that are distinctive in highlighting an object. Additionally, our context focuses on button press interactions that are familiar to users, regardless of background. More unique pick cues, such as Ghost Hand, may yield better task performance, and outcomes for unique interactions, such as those in Muresan et al.'s (2023) work.

### *Limitations and Future Work*

An area of future work is an exploration on minimizing resource conflict (Wickens, 2024) between look and pick cues. This could potentially further improve cockpit guidance. Future work includes on exploring the use of spatial audio for look cuing and its interaction with visual pick cues.

Another area of future work is an investigation of salience within cue. In our study, we implemented them with a vibrant magenta color to distinguish the cue within the environment. We acknowledge that salience maybe a contributing factor to our results, and believe salience is an avenue of future research.

## Conclusion

In this paper, we have presented a comparison study of look cues and pick cues. Through our study and its results, we revealed that Look Arrow and Pick Arrow are effective look cues in contexts involving a high density and volume of interaction candidates. This combination is the result of both the performative metrics as well as our participants' preference across our cues. We conclude that our work has the potential to extend to other real-world contexts, such as server rack maintenance. Our work provides further insight for future work of using interaction cues in high-density environments.

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