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Adapting Noticing Framework to Analyze Learner's Reasoning in VR-simulated complex scenarios

Herold PC[a*], Chandan DASGUPTA[b]
[a]*Educational Technology IDP, IIT Bombay, India*
[b]*Educational Technology IDP, IIT Bombay, India*
*herold@iitb.ac.in

Abstract: Car drivers learning to make decisions in Indian on-road scenarios is challenging. We designed and simulated a complex on-road scenario using virtual reality technology to help learners experience alternate perspectives of their driving actions. Our research focused on the cognitive influences on decision-making and adapted the noticing framework as the analytical lens. Four participants drove a car on virtual Indian city roads accompanied by a virtual conversational agent to elicit their reasoning while making decisions, followed by a stimulated recall protocol. We recorded each participant's actions and timestamped conversations with the agent and researcher. We inductively coded the noticing episodes and interpreted six types of conceptual relationships between the designed elements in the VR scenario. These interpreted codes could help us analyze the changes in a learner’s noticing patterns after taking alternate perspectives. This paper highlights the usefulness of the adapted noticing framework for future studies with multiple complex VR scenarios.

Keywords: VR simulation, Noticing framework, On-road scenarios, Learner's reasoning analysis

1. Introduction

A decision made by a human in complex scenarios requiring a time-bound response involves reasoning processes as characterized by naturalistic decision-making models (G. A. Klein, 1993). A vital component of that process involves the learner noticing and assessing the critical cues within the complex situation. In our research, we contextualized a complex scenario based on the frequently occurring events on Indian public city roads, simulated in a Virtual Reality environment. Existing work on VR-based decision-making and situation assessment has majorly modeled extreme accident situations as complex scenarios (Benvegnù et al., 2021) rather than frequently occurring events. VR interventions with affordance to take alternate perspective-views of an event (Kang et al., 2012) for decision-making have used ethical/moral frameworks (Sütfeld et al., 2017) to analyze their actions. These analytical lenses include both cognitive and affective influences on decision-making. Since capturing the affective responses of learners while driving is challenging, we focused our research on cognitive analytical methods. This scoping led us to the noticing framework in the education research domain. The existing noticing frameworks are predominantly derived in the teacher education and learning sciences field within a classroom setup (Amador et al., 2021). In this paper, we chose the noticing framework (Lobato et al., 2012) from learning sciences due to the possibility of mapping the conceptual element in our VR scenarios with the adapted components of the framework. In the VR intervention we developed, "PERSPECS," the learners/participants drive a VR-simulated car on Indian public city roads, making quick decisions at critical junctures, followed by taking an alternate perspective view of their actions. Our broader research objective is to investigate the effects of virtual reality perspective-taking on the learner's noticing behaviors in complex scenarios while driving a car on Indian roads. But, in this paper, we investigated a scoped-down research question: "How does the adapted noticing framework help capture the learners' assessment of critical cues within the complex VR scenarios?".

2. Noticing framework

Research on Noticing as a construct is derived from Goodwin's work on professional vision (Goodwin, 1994). For our study, we are considering the definition from the learning sciences group (Lobato et al., 2012), which says - Noticing refers to selecting, interpreting, and working with particular features or regularities when multiple sources of information compete for students' attention. While assessing a complex situation on Indian roads, noticing the critical cues from various sources of information across the sequence of events is essential for decision-making (G. Klein, 2008). Lobato's noticing framework maps well with our context, which consists of the following components: (i) Conceptual Relationships, (ii) Perceptual Features, (iii) Focusing interactions, (iv) Task features, and (v) The Nature of the Activity. We adapted the framework by modifying the domain-specific definitions for each component detailed in the following sub-section.

2.1 Framework adaptation

In our context, a 'Conceptual Relationship' is a relationship between different elements in a complex scenario that can be abstracted to signify a concept. The 'Perceptual Features' in our context help drivers orient toward the conceptual elements in the situation and notice the conceptual relationships between them. 'Focusing Interactions' refers to the virtual conversational agent (co-passenger) interactions with the participants, detailed in the next section, which can emphasize the various conceptual relationships. The 'Task Features' are the multiple on-road complex scenarios designed. The 'Nature of Activity' refers to the participatory roles of the driver and other actors in the VR environment, which regulates their possible actions. Particularly, the 'Conceptual Relationships" forms the basis of analyzing the noticing episodes coded from the participant's conversations with the agent, detailed in the discussion section.

3. Design of VR intervention

The noticing framework and the user study interviews conducted by us with ten car drivers commuting in Indian cities guide the design of the VR-simulated complex scenarios. The interview method was semi-structured, with questions to recall and reflect on their driving experience, for example – “*Can you share any instance where you had to break a traffic rule but felt your decision was right?”* The VR-simulated car also includes the design of a conversational agent guided by the scaffolding framework of pedagogical agents (Azevedo et al., 2004). We developed the scenario with the "Unity-3D" software. The scenario is experienced in VR using an "HTC-VIVE" head-mounted display and controlled using a physical steering wheel and brake/accelerator, as shown in Figure 1.

3.1 VR-simulated Complex scenario

A complex scenario is a scoped version of complex problems defined by (Funke, 2010), characterized by Complexity, Connectivity, Dynamics, and In-transparency in his work on cognition. In our research, we scope our scenarios that imbibe the characteristics of complex problems. In such complex scenarios, the decision-maker needs to notice and assess many elements involved in events that are changing dynamically and respond within 3-4 seconds. This response action results in immediate consequences on fellow human beings in that public scenario. The elements of each complex scenario are primarily characterized into the following four types – (i) Action Target - The action target of a scenario is humans who could bear the consequences of a participant's driving actions, (ii) Action Rule - The action rules of a scenario communicate the road rules to be followed by the driver in that context. (iii) Action Persuader

- The vehicles in the participant's vicinity which persuade or pressure the participants to make a quick decision, and (iv) Action Choice Primer - The vehicles in the participant's vicinity that could prime them on the available choices to act in that context. We derived these characteristics for each design element in the VR scenario from the affinity-map inferencing done on user study interviews.

Figure 1. Participant driving through the VR scenario (left) with the agent (middle) in the VR study setup (right).

A brief to the "Old man scenario" shown in Figure 1 – "You are on the way back to your home in your car to attend a dinner you had planned, and you have stopped in front of a traffic signal as the signal is RED (Action Rule). A few pedestrians and an old man (Action Target) are crossing the road. As the old man is halfway across the road nearing your car, the signal turns GREEN, the vehicles by your side start moving (Action Choice Primer), and vehicles behind you start honking (Action Persuader)." In this public scenario, the complexity is in assessing the situation with multiple events unfolding. The response time to decide and act in this complex scenario is around 3-4 secs. We validated this scenario using a survey questionnaire with 30 Indian drivers, who rated multiple Indian on-road scenarios based on the following factors - familiarity with them and level of difficulty in deciding an action.

3.2 Conversational agent

The Wizard-of-Oz method (Dahlbäck et al., 1993) is adopted to deliver the appropriate dialogues and animation gestures of the co-passenger to the participant, where a researcher will use the desktop keyboard to trigger them, as shown in Figure 1. This method allows the researcher to trigger multiple dialogues like - "*Hey, back there, how did you decide what to do?*" based on the response from the participant.

4. Method

The primary research question we are analyzing in this study is – "How does the adapted noticing framework help capture the learners' assessment of critical cues within the complex VR scenarios?". The participant's conversation with the conversational agent during the VR intervention and the participant's conversation with the researcher during the stimulated recall (Lyle, 2003) are coded as per the adapted noticing framework to interpret patterns for the primary research question. We used qualitative analysis with an inductive coding method (Cohen et al., 2017) to derive inferences.

4.1 Participants and procedure

The participants for the study were adults in the age range of 21 - 29 years with a minimum car driving experience of one year on Indian roads. Four participants volunteered for the study and signed the necessary consent forms approved by the institutional review board on campus. None of the participants had prior experience in using a VR car simulation. Participants take 3-level training inside the PERSPECS VR environment for 15 minutes to get accustomed to the car controls, gain familiarity with the city buildings and roads, and get familiar with the co-passenger avatar and self-avatar within the VR environment. After training, the participant experiences the complex scenario, i.e., the "old man scenario," as per the following sequence of steps for another 15 minutes. Firstly, as detailed in the design section, the participant drives the car, encounters the traffic lights with the old man and other pedestrians crossing the road, and acts at the critical decision-making point. After the action, the co-passenger has a conversation right after the critical decision-making point. Following the conversation, the participant experiences their action replay from the old man's perspective inside the VR environment (taking a perspective view is part of the broader research objective and not detailed in this paper), followed by a conversation with the co-passenger again. Ending the VR experience, the participant removes the VR HMD. The researcher then replays the screen recording on the desktop and conducts a stimulated recall protocol to reiterate their reasoning at the critical points in the scenario for 7-10 minutes.

4.2 Data sources and analysis

The data sources include (i) The video recording of the participant experiencing the VR intervention, (ii) The audio recording of the participant conversing with the co-passenger and the researcher, and (iii) The screen recording of the entire VR action-play by the participant. We used a qualitative analysis with an inductive coding method to derive inferences for our research question- "How does the adapted noticing framework help capture the learners' assessment of critical cues within the complex VR scenarios?". The transcripts between the co-passenger, participant, and researcher are encoded where the participant notices a conceptual relationship (CR) between the elements within the VR scenario. For instance, the conversation between the co-passenger and the participant in Table 1 is a noticing episode, which we then coded inductively into their various types.

Table 1. *A conversation excerpt between the co-passenger and a participant*

Speaker	Dialogue
Co-passenger	What all thoughts were there in your mind before acting back there?
Participant-3	I thought he is old; he was quite slow, so I thought I should give him time to cross the road.

In this conversation, the participant noticed the conceptual relationship of walking pace between the old man and the other pedestrians crossing the road. Noticing a conceptual relationship becomes one of the reasons for the participant's decision to give time for the old man to cross the road. Hence, similar conversations are "noticing" episodes that form the analysis unit. Following this, we inductively interpreted the types of noticing episodes and categorized them as shown in Table 2. We refined our categories through repeated discussions, where we examined their descriptions.

5. Results and Discussion

We encoded the conversations between the four participants, co-passenger, and researcher resulting in 29 noticing episodes. Out of these, ten noticing episodes were after the critical decision point, at an average of 2.5 episodes per participant, and 19 noticing episodes were after perspective-taking, amounting to an average of 4.75 episodes per participant. We interpreted these noticing episodes and categorized them into six types based on the conceptual relationships noticed between the designed elements of the VR scenario. The following subsection details the categorized noticing episodes with examples of such reasonings spoken out by the four participants.

5.1 Noticing episodes with conceptual relationship

The six types of noticing episodes were interpreted and categorized based on the conceptual relationships between the designed elements in the VR scenario are summarized in Table 2.

The top two types of noticing episodes observed across the four participants are "You Driving (YD) + Action Rule (AR)" with nine episodes and "Action Persuader (AP) + Action Rule (AR)" with six episodes. The following dialogue is an instance of the noticing episode interpreted as the type "Action Persuader + Action Rule" from the reasoning conversations of participant 4 – "*Ya, like this, even in the real world it happens, and I usually stop my vehicle, and if the vehicle behind don't notice I sometimes roll the window and signal using my hand that 'wait' so they usually understand. or sometimes I signal from the rearview mirror the vehicle behind can see my eyes when I give an expression, they usually understand and wait that something is there in front and they avoid honking. But if it was a teenager, they honk again and again.*"

Table 2. *Types of noticing episodes interpreted with description.*

Noticing types	Dialogue
Action Target (AT) + You Driving (YD)	When the participant reflects and talks on conceptual relationships like the old man's (AT) response in relationship with their vehicle's (YD) behaviors towards him and its immediate consequence towards the old man.
Action Persuader (AP) + Action Target (AT) /Action Rule (AR)	When the participant reflects and talks on conceptual relationships like the behavior of the car behind (honking) (AP) in relation to old man's behavior (AT) or traffic signal (AR).
Action Choice Primer (ACP) + AT/AR	When the participant reflects and talks about conceptual relationships, like other vehicle's response (ACP) in relation to old man's (AT) behavior or traffic signal (AR).
YD + AP/ACP/AR	When the participant reflects and talks on conceptual relationships between their car (YD) and behaviors of the honking vehicle behind (AP) or other vehicles by the side (ACP) or change in traffic signal light (AR).
Retro (R) + AT/AP/ACP	When the participant reflects and talks on conceptual relationships between an object in the scenario and retrospective accounts (R) of that object from previous experiences.
AT + AR	When the participant reflects and talks on conceptual relationships like old man's (AT) behavior in relationship with other pedestrians while crossing the road (like walking pace) or in relation to changes in traffic signal light (AR).

The types of noticing episodes inductively interpreted and categorized in Table 2 based on the conceptual relationships will help critically analyze the participant's reasoning while making decisions in complex scenarios. For our broader research objective of investigating the effects of virtual reality perspective-taking, this approach will allow us to explore the change in noticing patterns across multiple VR scenarios. For instance, in the "Old man scenario," the noticing episodes of type "Action Target + You Driving" were interpreted differently by the participant before and after perspective-taking. One of the dialogues of Participant 4 before perspective-taking is – "*Now what do I say about that, signal was RED, but then the old man was there, so I just stopped, and also there is a rule that you have to give first priority to the pedestrian. I am in a car so I can go easily but they are walking so".* On the contrary, the dialogue of Participant 4 after perspective-taking is – *"Actually in that view I was just judging myself, so at that time the car shook a bit, because at that time when I was moving right it was going too much right and likewise for left, So if I were an old man I would never cross the road seeing someone shake the car like this, thinking that they might hit me. Also,* *the car came back and forth and I felt from the old man's view that if it was the old man, then he would have got scared.*". These coded noticing episodes with six categories indicates that the adapted noticing framework used to design the VR intervention is meaningful and valuable for more extensive studies with multiple complex VR scenario in our context. The number of participants is a limitation of the study, and if the number is higher, there is a possibility of interpreting more types of noticing episodes in the future. One of the challenges in adapting the noticing framework is to identify the appropriate conceptual elements within our context and map them to the definition of noticing framework components.

6. Conclusion

Using advanced virtual reality technology, we developed complex scenarios that can show alternate perspectives to help car drivers learn decision-making in complex on-road scenarios. This paper discusses how we adapted the noticing framework, developed a complex VR scenario, and inductively interpreted the participant's reasoning by categorizing the noticing episodes. Four participants drove a car on virtual Indian city roads accompanied by a virtual conversational agent to elicit their reasoning while making decisions. We interpreted the noticing episodes into six types of conceptual relationships between the designed elements in the VR scenario. In future work, we can use the identified noticing characteristics to identify and analyze the patterns in noticing behaviors before and after takings perspective views across multiple complex scenarios in the Indian road context. This paper demonstrates the usefulness of the adapted noticing framework for such contexts and can be used by Learning Sciences and Education researchers for VR-based interventions.

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