Does your Seat Affect your Ego?: An Observational Study on Egocentric and Exocentric Frames of Reference Used by Vehicle Passengers

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Student R&D Paper

This paper represents the work of VEMI Lab students at the University of Maine during Rapid Research Week, a one-week crash course in human subject research where students design, conduct, and author a research study on current topics. The paper has undergone a peer-review and revision process led by graduate students.

Hosted on ResearchGate, the paper can be cited using the following reference format:

Brown, J. R., Rumsey, R., & Fahey, C. (2024). Does your Seat Affect your Ego?: An Observational Study on Egocentric and Exocentric Frames of Reference Used by Vehicle Passengers. *VEMI Student Publications*, 4(3).

Background and Purpose

A crucial first step in describing spatial orientations and the spatial locations of objects in an area is to define a frame of reference (FoR) that guides the descriptive language. By understanding how people interpret and act in the world around them, we can better understand the language needed to effectively communicate with passengers traveling in an autonomous vehicle. In an egocentric FoR, spatial descriptions are based on a person's perspective and orientation while an exocentric FoR is from the perspective of an external view. In the context of traveling within a vehicle, passengers can describe objects outside of the vehicle from their personal perspective (egocentric FoR) or from the perspective of the vehicle (exocentric FoR). In a standard 5 passenger vehicle, passengers are situated in seats that face the front of the vehicle and align the passengers with the vehicle's orientation. This means an object in front of the vehicle is also in front of the passengers and an object to the right of the vehicle is also to the right of the passengers. Now, what if a passenger is seated in a vehicle in which the passenger's orientation is not aligned with that of the vehicle? Examples of this type of seating can be commonly found on public transportation; predominantly buses and trains. Passengers can usually choose to sit in front facing, rear facing, and sideways style seats. A study conducted by Wardman and Murphy (2015) found that train passengers preferred to sit in front facing seats near windows if possible - although it was mentioned that avoiding other passengers and their belongings may have been a significant influence. We speculate that a passenger's preferred orientation within a vehicle may influence the frame of reference they use, whether they are aware of this decision or not.

During our review of past relevant literature, we did not come across a study that explored changing a vehicle passenger's orientation to study if there is an effect on the frame of reference they are using to describe spatial objects. We are interested in this kind of exploration because of our future work with autonomous vehicles at the VEMI Lab. The in-lab autonomous vehicle (AV) simulator, modeled

after future industry designs, has a C type seating arrangement that allows for passengers to sit in front facing, rear facing, and sideways style seats which are similar to train seating. This style of seating is not the standard for cars we see driving on the roads today and presents a new challenge for vehicle passengers: How will spatial information be accurately conveyed by the vehicle to individual passengers sitting in different orientations? Phrases like, "exit on the left," "move forward," and "there's a traffic cone on the right" are now ambiguous unless a single frame of reference is utilized.

This dilemma is similar to the one put forth by a 1998 study on different FoRs in virtual 3D navigation. Participants were asked to use a joystick to navigate to a target location in three different FoRs and it was found that an exocentric FoR had the best overall performance (McCormick et al., 1998). Through a set of experiments, Wang et al. (2000) posits that humans maintain egocentric representations of surrounding objects, and rather than switch their representations into a new reference frame, they update their egocentric representations as they move. However, these experiments involved pointing tasks before and after disorientation to determine object locations rather than using descriptive language to identify the spatial position of the objects. A study on language in Peru tested whether environmental experiences can influence a person's default frame of reference when communicating with others. It was found that among a particular group of people with more herding experience, exocentric language was used more frequently than egocentric language (Shapero, 2017).

Our study aims to fill the gap between a vehicle passenger's orientation, controlled by their seat position, and the frame of reference they use to communicate spatial information.

Hypotheses

The following hypotheses were formed regarding vehicle passengers' consistency in a given frame of reference:

H_0 : Passengers traveling in a vehicle will use a consistent frame of reference; either the vehicle's FoR or an egocentric FoR.

H_1 : Passengers traveling in a vehicle will <u>not</u> use a consistent frame of reference; a combination of the vehicle's FoR and an egocentric FoR.

Methods

This study was conducted during the VEMI Lab's annual Rapid Research Week which is designed to challenge students to complete an entire research study in a condensed time frame of a single week. Using the AV simulator housed inside the VEMI Lab, 12 participants recruited from the lab completed 3 trials in 2 conditions, for a total of 6 trials. Two researchers were involved with running the within-subjects study. Researcher 1 (R1) proctored the experiment in the simulator and researcher 2 (R2) ran the computer controlling the simulator and the experimental virtual environment.

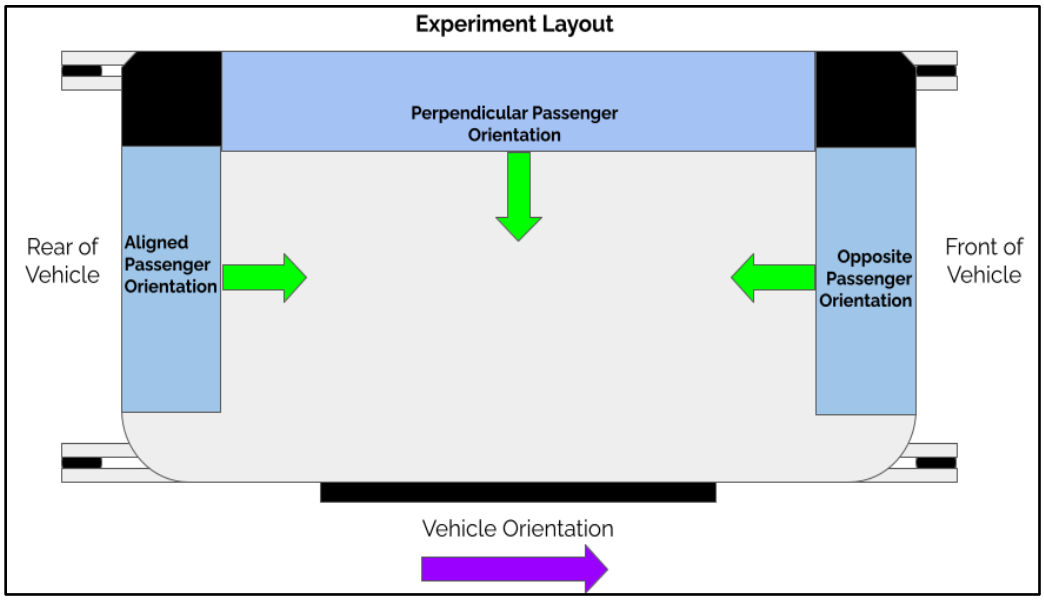


Figure 1: The experiment layout within the AV simulator. Each bench aligns the passenger in a different orientation; aligned, perpendicular, and opposite to the vehicle's orientation.

The experiment began with the vehicle moving in its forward direction[1] and the participant sitting in one of the three bench seats in the simulator. Figure 1 depicts the experimental layout of the AV simulator. The three benches in the simulator are situated in three different orientations. One seat aligns the participant with the vehicle's orientation, one seat positions the participant perpendicular to the vehicle's orientation, and the last seat places the participant so that they are sitting opposite to the vehicle's orientation. The seat position order was counterbalanced between subjects and R1 directed the participant which seat to sit in and at what time. The vehicle would travel one block in the simulated environment along a straight path, stopping at an intersection with a traffic cone placed on one side of the vehicle. Once stopped, R1 asked the participant two questions: 1) What is the direction of travel? and 2) In what direction is the traffic cone? The first question requires the participant to think about the motion they are experiencing during travel while the second question prompts the participant to think about how they would describe the location of an object outside of the vehicle. These questions were intentionally worded in a way that did not prompt the participant to answer in a given frame of reference. The participant was not allowed to ask clarifying questions and could only respond with one of four choices: forward, backward, left, and right. After answering the two questions, the participant was guided to their next seat position and R1 would signal to begin the next ride. This procedure was repeated until the participant answered questions for each of the three seats in the forward moving condition.

After the forward condition, R2 would then load the reverse moving condition and start the first reverse ride after the participant was seated. Again, at each stop, the participant was asked the two questions: 1) What is the direction of travel? and 2) In what direction is the traffic cone? This was repeated until the participant had sat in all three seats and answered all of the questions about the vehicle motion and traffic cone locations for the reverse condition. Once complete, R1 asked a series of short

[1] The AV simulator does not have a defined front or rear due to the absence of a steering wheel. To define a vehicle frame of reference for the study, the markings "front of vehicle" and "rear of vehicle" were added to the inside cabin and explained to the participants during the instructional period.

post-test questions and debriefed the participant on the purpose of the study in detail. All participant responses were recorded using the Qualtrics survey platform.

Results

It was found that 7 participants remained in one FoR throughout the entire experiment and 5 participants were inconsistent with their choice of FoR. Of the 7 participants that were consistent, 3 used an egocentric FoR and 4 used the vehicle's FoR. 7 participants were consistent during the forward condition with 3 participants using an egocentric FoR and 4 participants using the vehicle FoR. 10 participants were consistent during the backward condition with 4 participants using an egocentric FoR and 6 participants using the vehicle FoR. With a McNemar Test, we found no statistically significant difference in the consistency proportions between the two conditions ($p=0.500$).

When comparing participant consistency between the seats that were not aligned with the vehicle's orientation (perpendicular seat and opposite seat), 9 participants used a consistent FoR while in the perpendicular seat and 7 participants used a consistent FoR when sitting in the opposite seat. Among those that were consistent, 4 participants used an egocentric FoR and 5 participants used the vehicle FoR while in the perpendicular seat and 2 participants used an egocentric FoR and 5 participants used the vehicle FoR while in the opposite seat. With the McNemar Test, we did not find a statistically significant difference in the proportions of consistent and inconsistent FoRs while participants sat in the perpendicular seat or the opposite seat ($p=0.625$).

When comparing consistency between the two questions, the travel question prompted 10 participants to answer consistently with 7 participants using an egocentric FoR and 3 participants using the vehicle FoR. The traffic cone question prompted 8 participants to answer consistently with 4 participants using an egocentric FoR and 4 participants using the vehicle FoR. The McNemar Test again did not show a significant difference in consistency proportions between the questions ($p=0.375$).

In the post-test survey, a question was asked about the participant's preferred seat. 9 out of 12 participants preferred the aligned seat and the other 3 participants preferred the perpendicular seat. A majority of the participants' explanations mentioned being more comfortable and being able to easily view the surroundings.

Table 1: Participant consistency for each experimental variable, their corresponding p-values, and FoR.

Experimental Variable		Consistent FoR	Inconsistent FoR	McNemar Test	Egocentric FoR	Vehicle FoR
Direction / Condition (N=12)	Forward	7	5	*p = 0.500*	3	4
	Backward	10	2		4	6
Seat Position / Orientation (N=24)	Perpendicular	9	3	*p = 0.625*	4	5
	Opposite	7	5		2	5
Question Type (N=24)	Travel	10	2	*p = 0.375*	7	3
	Object	8	4		4	4

We fail to reject the null hypothesis that a passenger keeps a consistent frame of reference while traveling in a vehicle. We expected to observe a shift in FoR when participants changed their orientation in the vehicle and then had to answer questions about an object outside of the vehicle. However, more than half of the participants stayed consistent in a FoR for each condition. A summary of the results can be found in Table 1 above.

Discussion

While the results from this study did not yield statistically significant findings, we did reveal interesting insights with regard to participants' consistency with frames of reference during travel in a non-standard vehicle layout. Our findings suggest that a majority of participants maintained a consistent FoR throughout the experiment, indicating a strong preference for a particular perspective in the vehicle. When examining the specific FoRs, we observed a relatively equal distribution between egocentric and vehicle FoRs. This suggests that participants' choice of FoR is not solely determined by the vehicle's orientation but may also be influenced by individual preferences, cognitive factors, or task demands. Our comparisons between conditions further highlight the consistency of participants' FoRs. Despite changes in vehicle orientation and question type, a substantial number of participants consistently used the same FoR. This suggests that once a FoR is established, it can be maintained even when faced with varying contextual cues. The post-test survey revealed a strong preference for the aligned seat, with participants citing comfort (i.e., trying to minimize motion sickness) and visibility of the surrounding environment as key factors. This is supported with previous research suggesting that passengers may be more likely to be seated in an aligned position that has a clear view of the external environment (Wardman & Murphy, 2015). While our results do not provide definitive evidence for a universal tendency to maintain a consistent FoR, they do offer valuable insights into how non-standard vehicle layouts may influence passenger FoR. Future research could explore the role of individual differences (e.g., spatial abilities, personality traits, language) in FoR selection, as well as the impact of more complex driving scenarios (e.g., intersections, traffic congestion) on passenger FoRs.

Limitations

This week-long rapid research study had several constraints, but development time and the number of participants available were the main factors. The study's rapid development affected the quality of our virtual environment used in testing. The environment caused some minor motion sickness and slight confusion for some of our participants. These could have been avoided if resources and time allowed for screening out participants susceptible to motion sickness and we provided criterion tests to check participant understanding with the study tasks. Another factor that likely influenced the results of this study was the fixed condition order, in which participants experienced the forward direction first, then the reversed direction second. The fixed condition order was originally chosen to simulate a realistic driving scenario; most vehicles and passengers experience travel in the forward direction. But this may have worked against the experimental design by causing a potential learning effect. This may explain why participants were more consistent in the backward condition. Another possible variable in skewing results could be the "Front of Vehicle" and "Back of Vehicle" labels inside of the AV simulator. These were used to define the vehicle's orientation and thus the vehicle FoR. With a standard vehicle, the front and rear of the vehicle is clear to the passenger. By copying this in the AV simulator, we may have unintentionally primed the participants to think of the vehicle's orientation and therefore use the vehicle's FoR. As mentioned above, there were also multiple instances of participants feeling motion sickness, this

caused those individuals to prefer one specific seat in order to lessen that feeling. Since the participants were more focused on their feeling of sickness, it is likely they were less focused on the task at hand and a specific FoR.

Future Work

If research is continued, it is likely that running 12-24 more participants in this study over a longer span of time would provide enough data for potential significant results and determining if participants have a clear preferred frame of reference. An increased number of participants may also allow for an analysis of personal, cultural, and language effects on a passenger's FoR. Further development of the virtual environment may also improve this study. A higher fidelity virtual environment may decrease the risk of motion sickness of future participants and create a greater sense of immersion in the environment. This improved environment may allow for more complex tasks, that probe FoR reasoning, to be implemented. For instance, it could be interesting to include a complex spatial task, delivered by the autonomous vehicle rather than the researcher, at a congested intersection to observe the effects of human-vehicle communication on FoR and spatial reasoning. With some of the aforementioned modifications, including a larger participant pool, the results of this study may have a larger impact on the future of autonomous vehicle development regarding passenger and AV communication.

Acknowledgements

This project was funded by the VEMI Lab and supports the Lab's ongoing autonomous vehicle research. The authors would like to recognize and thank the Rapid Research Week faculty mentor team consisting of Dr. Richard Corey, Dr. Nicholas Giudice, Dr. Caitlin Howell, Dr. Paul Fink, Grant Beals, and RJ Perry. In addition, a special thank you goes out to the participants who contributed to this research.

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