Exploring the Impact of Cultural Background on Visual, Auditory, and Tactile Reaction Time

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Abstract

Reaction time studies have been essential to the development of various devices and systems such as emergency alerts and notification systems. However, these studies have rarely been conducted with culturally diverse samples. This study uses custom software and simple reaction time tests to investigate the relationship between an individual's cultural background and their reaction time to visual, auditory, and tactile stimuli. Overall, there was no significant relationship between cultural groups and reaction times. However, results from this study can inform the design of future experiments that involve reaction time and online experiments.

Keywords

Cognitive processes, Human-computer interaction, Reaction time, Time measurement, Time factors.

Introduction

The field of human-computer interaction (HCI) is built upon social and behavioural science principles with deep roots in sociology and psychology. Specifically, HCI research has previously been influenced by experimental psychology research which focuses on understanding the variability in human behaviour and performance [2].

One of the major factors contributing to this variability is cultural background. The community and environment in which an individual develops has a significant effect on their behaviour and cognitive processes [7]. Hence, this would affect how an individual interacts with computers and technology. However, experimental psychology studies have historically not included culturally diverse samples. They have focused primarily on samples consisting of individuals from White, Educated, Industrialised, Rich, and Democratic (WEIRD) societies [7]. Consequently, it is difficult to assume that these results (and by extension, the results from the consequent HCI studies) can be generalised to a large, global population.

There are many measures of human performance, however, this study focuses on one of the most commonly used measures – reaction time (RT). Reaction time is defined as the delay between the occurrence of a change in stimuli and the initiation of a human response to it [6, p. 95]. It is known that an individual's reaction time differs depending on the stimulus: 150 ms for auditory, 200 ms for visual, 300 ms for smell, and 380 ms for pain [1, p. 41]. Studies with a focus on reaction time have led to significant findings in the realm of HCI including the optimisation of input devices like the mouse [9] as well as the development of emergency notification systems like those used in vehicle collision systems [8]. Notably, the latter example depends on the average reaction time to three different stimuli – visual, auditory and tactile (vibration/haptic). Typically, research in HCI is centred around simple reaction time (for a single, fixed stimulus) but with the rapid development of technology, additional research is required to investigate the reaction times for a combination of stimuli.

With the increasing universal reliance on technology, it is imperative to examine the role that culture plays in various psychological phenomena. The objective of this study is to investigate whether cultural background has a significant impact on the reaction time for visual, auditory, and tactile (haptic) stimuli. The findings of this study could emphasise the need for integrating cultural considerations in the development and design of user interfaces and systems in order to enhance the inclusivity and usability for a global population of users.

Related Work

This section focuses on recent studies that have examined sensory and cultural dimensions in reaction times, providing a framework for understanding how HCI can adapt to these influential factors. Analysing some previous work, a variety of concepts can be explored such as Duinkharjav et al.'s probabilistic model on image (visual) features affect eye saccade latency, specifically in response to visual cues [3]. Duinkharjav et al.'s study demonstrates that certain visual attributes, such as contrast, colour and spatial frequency significantly influence reaction times during saccadic movements. This model, tested in a range of visual settings, highlights how altering visual parameters can influence cognitive processing speeds, leading to faster saccadic responses [3]. The research delves into perceptual factors that must be considered when designing visual interfaces, to optimise response time and user engagement by tailoring visual features to suit the user's perceptual capabilities. Complementing this, Lyons' work [5] demonstrates the value of customisable visual parameters in wearable HCI, allowing designers to improve user interaction by mitigating delays in visual processing. He examined the impact of visual parameters, such as icon size, contrast, and positioning on smartwatches, where optimising for smaller screens and interfaces can significantly reduce reaction times, facilitating smoother interactions. The study's findings suggest that even subtle adjustments to visual prominence can lead to improved usability in wearable technology, an area where screen space and clarity are often limited [5].

On the other hand, Kubota et al.[4] explore the naturalness of reaction times in sensory-focused interactions (primarily visual, auditory, and tactile stimuli). Their study assessed how users reacted to specific cues by analysing turn-around behaviours, intending to establish a natural, contextually appropriate range of response times. Their study concluded that reaction times for auditory stimuli tend to align with the natural auditory processing rhythms of users, noting that auditory cues often elicit faster responses [5]. These results are particularly relevant in scenarios such as auditory navigation assistance or emergency alerts, where rapid auditory response can enhance user experience and improve perceived intuitiveness in auditory-based interfaces [5].

In addition to single-modality studies, Yoshida et al. [10] explored how multimodal combinations of audio, visual, and haptic stimuli influence reaction times, focusing on the response patterns elicited by varying stimulus combinations. According to Yoshida et al., synchronised multisensory stimuli resulted in faster and more accurate user responses compared to unimodal cues. This multimodal integration leverages natural sensory synchronisation, which enhances response efficiency. This finding has significant implications for designing feedback in HCI, suggesting that systems utilising combined sensory modalities can offer more effective interaction methods, particularly in immersive or accessibility-focused applications [10]. Ultimately, these studies illustrate the critical role that sensory modality plays in determining reaction times across various contexts and platforms. This area of focus in HCI design aids in understanding the sensory depth of an individual to create efficient, user-oriented interfaces and interaction modes. Building on the current literature, our study will examine how sensory modalities—tailored to cultural differences—affect reaction times, contributing to the development of more inclusive and context-responsive HCI systems.

Methodology

Participants

The experiment recruited 30 participants – 10 individuals from each of the following cultural origins: North American, Asian, and Latin/South American. Participants were primarily university students (17 women, 12 men, and one gender non-conforming), aged between 18 and 26. All participants were recruited through snowball sampling. Participation was voluntary and no compensation was provided.

Apparatus

Hardware: All tests were executed using a laptop with at least one speaker and capable of delivering vibrations.

Software: This experiment used a custom software[1] (created with *PychoPy*[2]) to present visual, auditory, and tactile stimuli and log reaction times with millisecond precision. For visual stimuli, a colour change from white to red prompted a response, as demonstrated in Figure 1). For auditory stimuli, the software played a short notification sound through the speaker. Tactile stimuli were delivered through the device's vibration features, and participants placed

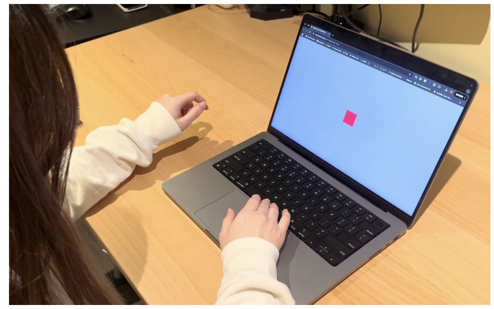

Figure 1: A participant performing the auditory response in a quiet space.

Figure 2: A participant performing the tactile response task, placing the non-dominant hand on the speaker.

their non-dominant hand on the speaker to feel the vibrations, as demonstrated on Figure 2). The experiment was hosted online through *Pavlovia.org*[3].

Procedure

All participants completed the study in person with one of the researchers or they were sent a link to complete the experiment on their computers. Researchers were available whenever experiments were being conducted online, in the event that participants required assistance or clarification.

Before completing the experiment, participants completed a brief questionnaire to collect demographic information such as age, handedness, gender identity, and first language. Participants then completed 10 trials for visual, auditory, and tactile stimuli, for a total of 30 trials per participant. Participants were instructed to respond as quickly as possible by pressing the space bar on the laptop with their dominant hand, as shown in Figure 1.

The software recorded the reaction time for each trial. The mean reaction time for each participant was calculated across the 10 trials for each stimulus type. The entire experiment took approximately 5-10 minutes per participant.

Design

This study used a 3 × 3 mixed design with the following independent variables and levels:

[1] https://run.pavlovia.org/prach19/reaction-time
[2] https://psychopy.org/
[3] https://pavlovia.org/

- **Cultural Background** (self-identified): North American, Asian, and Latin/Central/South American.
- **Stimulus Type**: Visual, Auditory, Tactile.

The following dependent variables were recorded:

- **Reaction Time (ms)**: Time taken to respond to each stimulus.

Each block of trials was presented to participants in different orders, based on the assigned sequence to ensure counterbalancing. This minimised the chance of any order effects and enabled reliable comparisons across the three sensory modalities. There were a total of six counterbalance groups that were randomly assigned to each participant.

Participants completed 10 trials for each sensory modalities, totaling 30 trials per participant (10 trials × 3 stimuli). With 30 participants, the study included a total of 900 trials (30 trials × 30 participants).

Cultural Group	Mean Visual RT	Mean Auditory RT	Mean Tactile RT
North American	302	298	624
Latin/South American	335	366	1239
Asian	283	460	524

Table 1: Average reaction time (ms) by cultural group.

Results and Discussion

Once each participant completed the experiment and submitted the form, the results were automatically saved to a database only available to the researchers. The results were collated, compared, and analyzed. Overall, there were observed differences in reaction times for each cultural group however the results were not statistically significant (F(2, 27) = 2.210, p > .05), indicating that cultural background has no impact on an individual's reaction time.

Reaction Time

For this study, a participant's reaction time for a sensory modality was the average of their times across all 10 trials. Then, the average reaction times for each cultural group were calculated, the results of which are summarised in Table 1. As seen in Figure 3, the average reaction time to changes in visual and auditory stimuli similar across all three groups was similar (with differences less than 50 ms). However, there is a larger observed variance in the reaction time to tactile stimuli with the Latin/Central/South American group performing (on average) 66% slower than North Americans and 81% slower than Asians. However, the effect of cultural background on reaction time was not statistically significant ($F_{(2,27)} = 2.210, p >$ .05).

The reasons behind the possible observed differences could include distractions in the participants' environment. Though each participant was informed that the tests should be done in a quiet environment, we did not place any restrictions on what that meant. The study was designed to be conducted in a semi-natural environment where the participants were comfortable and possibly not as alert as they would have been in a controlled environment. Doing so would aid the external validity of the results, however, it is worth questioning if a more controlled environment would have affected the results. Similarly, there are limitations to conducting a study online. Particularly, there was no control over the participant's interpretation of each task. Instructions were provided before the experiments and before each block of trials, prior to the presentation of a new stimuli type. However, since participants were from a range of cultural backgrounds with different language proficiency levels, there is a chance that instructions were misunderstood, leading to delays in reactions.

On the other hand, the effect of trial number was statistically significant ($F_{(9,243)} = 4.398, p < .0001$). This demonstrates that participants improved in performance with each trial, indicating that there exists some form of learning effect (Figure 4). Consequently, we can assume that participants would have improved their reaction time if the study was designed to include more trials thus potentially altering the results. Participants were encouraged (but not forced) to test the software prior to beginning the experiment. Only two participants opted to complete a practice session while the rest opted to complete the actual experiment immediately. While there may be numerous reasons why participants made these decisions, the results of this study may change with the level of practice and familiarity that the participants have with the software.

Participant Feedback

After completing the experiment, participants were asked to rate their familiarity with reaction tests on a 5-point Likert scale, ranging from "Not Familiar" to "Very Familiar". Most participants had a fair amount of knowledge regarding reaction time tests, with an average rating of 3.3 out of 5. While the study aimed to recruit individuals from a range of educational backgrounds and experience, the familiarity of reaction time tests may have had an effect on the results, similar to the aforementioned impact of practice and learning on reaction time.

Participants were also asked to rate their comfort level with the experiment on a 5-point Likert scale, ranging from "Very Uncomfortable" to "Very Comfortable". Participants were instructed to consider how much assistance they required to complete the experiment as well as reflect on how well they think they performed. Overall, participants indicated that they were very comfortable completing the experiment with an average rating of 4.1 out of 5. This indicates that the participants faced minimal software issues and that most of the sample could successfully complete the experiment without the assistance of the researcher.

Conclusion

This study explored how reaction times to visual, auditory, and tactile stimuli vary across cultural backgrounds, revealing potential

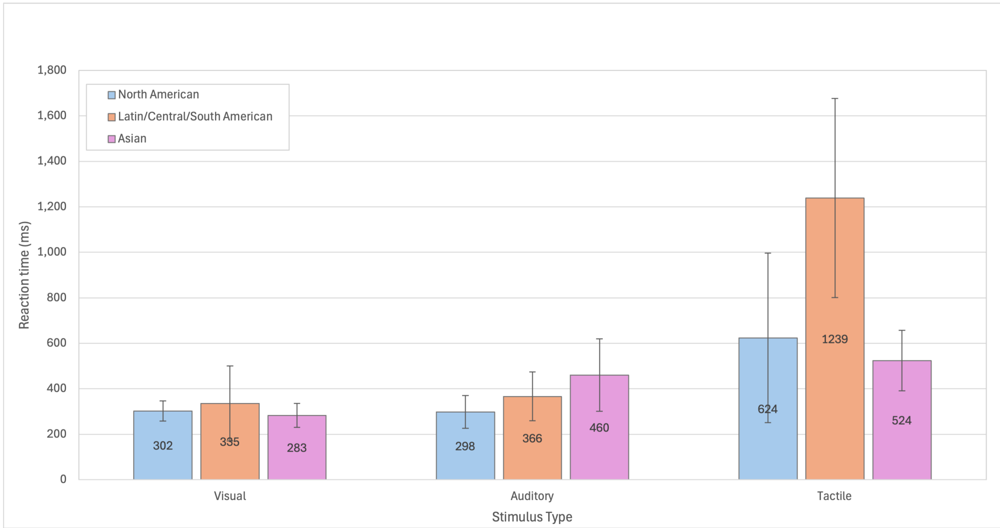

Figure 3: Average reaction time (ms) by stimulus type and cultural group. Error bars represent ±1 SD.

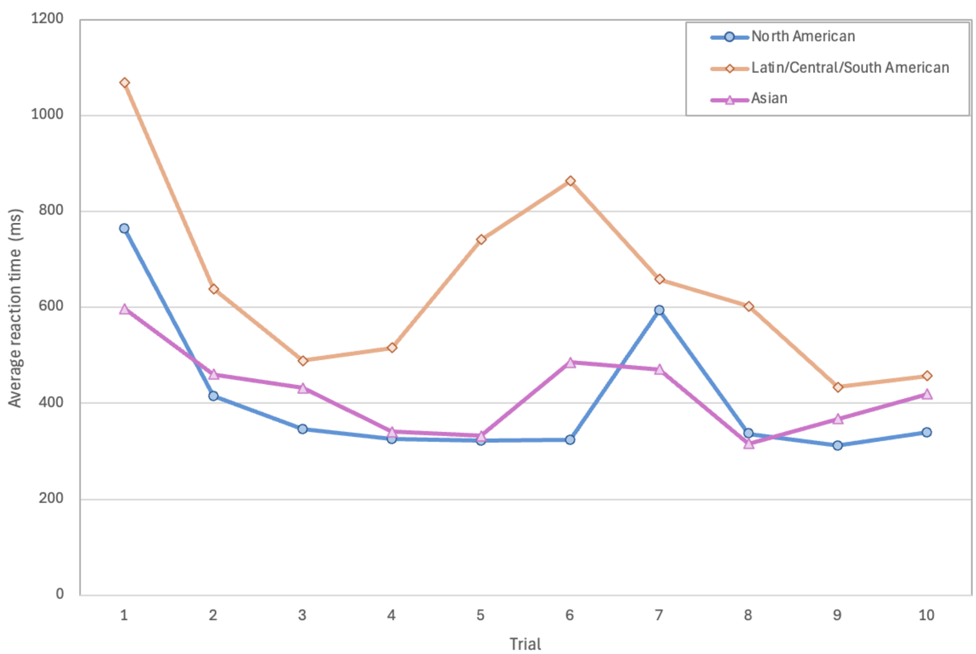

Figure 4: Average reaction time (ms) by culture group, across trials.

differences that could have significant implications in the field of HCI. While no statistically significant differences were found, the observed variance in reaction times, particularly among participants from Latin/Central/South America, suggests potential avenues for further exploration. Notably, the significant effect of trial number indicates a learning effect, as participants consistently improved their performance with repeated trials. Additionally, the observed variance in tactile response times raises important questions regarding sensory modality prioritisation across cultures, which has implications for designing responsive and inclusive systems.

The findings emphasise the need to design culturally aware systems, particularly for applications that rely on quick sensory interactions, such as emergency notifications, gaming interfaces, and assistive technologies. Beyond these domains, this research can inform advancements in virtual and augmented reality environments, where rapid responses are critical for immersive experiences. Moreover, it can also be beneficial in the healthcare industry, through the development of telemedicine platforms and rehabilitation programs, by tailoring interfaces to account for sensory differences across cultural groups. By doing so, developers can create equitable and effective solutions that meet the needs of diverse populations.

Overall, this study contributes to a growing understanding of cultural influences on sensory processing and reaction times. However, several limitations remain, such as the sample size, the controlled lab setting, and the scope of cultural groups included. Future research should address these limitations by expanding participant pools to include a broader range of cultural backgrounds and age groups, exploring additional sensory modalities such as olfactory and gustatory stimuli, and testing reaction times in real-world, dynamic scenarios. Furthermore, longitudinal studies could examine whether exposure to multicultural environments influences reaction time in the long run.

In conclusion, this study highlights the intricate interplay between culture, sensory processing and reaction times. By addressing these factors, future research can inform the development of HCI systems that are inclusive, and equitable, fostering accessibility and performance in a globally interconnected world.

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A Appendix

A.1 Questionnaire

(1) Please view and sign the following consent form: EECS 4441 Consent Form. Do you consent to participating in this study?
- Yes
- No

(2) Participant Initials:

(3) Participant Number (this is automatically generated in the experiment):

(4) What is your experiment group?:

(5) Gender Identity:
- Man
- Woman
- Non-binary

(6) Age:

(7) Which cultural group do you most identify with:
- North American
- Latin/Central/South American
- Asian

(8) Is English your first language?
- Yes
- No

(9) Handedness:
- Right-handed
- Left-handed
- Ambidextrous

A.2 Feedback form

(1) How familiar were you with reaction time tests prior to this study?
- 1 - Not familiar
- 2 - A little familiar
- 3 - Somewhat familiar
- 4 - Familiar
- 5 - Very Familiar

(2) Please rate your comfort level with the experiment.
- 1 - Not familiar
- 2 - A little familiar
- 3 - Somewhat familiar
- 4 - Familiar
- 5 - Very Familiar

(3) Any additional thoughts or concerns that you would like to share?