Mimicker-in-the-Browser: A Novel Interaction Using Mimicry to Augment the Browsing Experience

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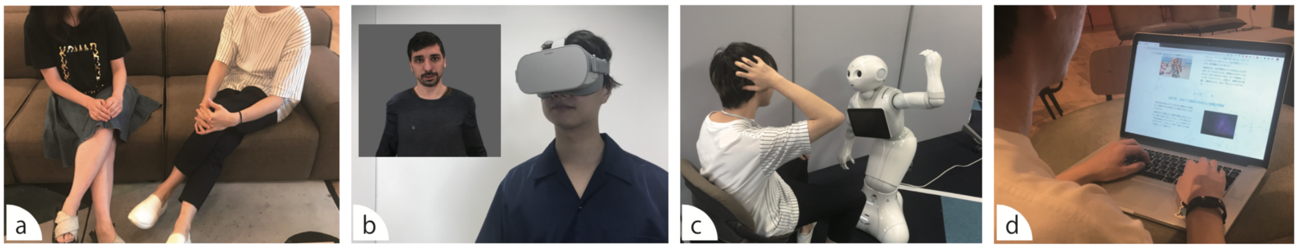

Figure 1: Given that (a) mimicry provides mimickees with favorable feelings in human-to-human conversation, previous studies leveraged this effect in (b) virtual reality and (c) human-to-robot communication using external sensors. Our work extends this application area into our daily lives using (d) a web browser, a much more scalable platform.

ABSTRACT

Humans are known to have a better subconscious impression of other humans when their movements are imitated in social interactions. Despite this influential phenomenon, its application in human–computer interaction is currently limited to specific areas, such as an agent mimicking the head movements of a user in virtual reality, because capturing user movements conventionally requires external sensors. If we can implement the mimicry effect in a scalable platform without such sensors, a new approach for designing human–computer interaction will be introduced. Therefore, we have investigated whether users feel positively toward a mimicking agent that is delivered by a standalone web application using only a webcam. We also examined whether a web page that changes its background pattern based on head movements can foster a favorable impression. The positive effect confirmed in our experiments supports mimicry as a novel design practice to augment our daily browsing experiences.

CCS CONCEPTS

• **Human-centered computing → Web-based interaction**; *Interactive systems and tools*; • **Applied computing** → Psychology.

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KEYWORDS

Mimicry; Browser-based interaction; Computer-mediated communication

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1 INTRODUCTION

Mimicry – the subconscious imitation of postures, facial expressions, mannerisms, and other movements – is considered by researchers to be important to understanding social interaction [12]. The fact that such mimicry increases liking between interaction partners was conceptualized by Chartrand and Bargh [11] as the *chameleon effect.* They also found that their experiment confederates who intentionally mimicked participants were more liked than confederates who did not. The effect of the conscious imitation on liking was later confirmed in various settings such as ordering at a restaurant [55], making a deal [39], and conducting a business interview [47].

This effect of mimicry has also been confirmed in computer-mediated communication. [3]. Shimada et al. [49] confirmed that this positive effect occurs even when a humanoid robot imitates the movements of participants. Based on these favorable results, computers could achieve more preferable and persuasive communication with humans in the future. However, mimicry has not been fully exploited in real-world applications.

One of the major factors hindering such applications is the difficulty and cost of capturing user movements. Previous methods have relied on sensors to capture the postures of a user, which requires physically controlled settings such as virtual reality environments using a head-mounted display or robot-based interactions using an infrared sensor. Consequently, this area of application is somewhat distant from other means of information transfer in our daily lives.

We anticipate that if this result could be replicated on a more popular platform without external sensors, the mimicry effect would be exploited in other communication spaces. In this respect, with the development of deep learning techniques, we can now estimate a human pose with a high degree of accuracy using only a single RGB camera [62]. In particular, it is possible to estimate a human pose using a web browser, which is installed on almost all computers [50]. Therefore, we first investigated whether the mimicry effect can be realized in a scalable way through interactions with an agent using a web browser (Figure 1).

Furthermore, to provide a practical example of exploiting the mimicry effect in a web browser, we examined the impression of participants who visited our gimmicked page through a user study. In detail, we showed that the geometrical pattern on the background of the web page, which moves congruently with the head pose of the users, induces positive ratings of favorableness.

In summary, our contribution in this paper is three-fold.

- We confirmed that mimicry effect can be reproduced with a web browser and webcam while previous research assumed additional sensors.
- We presented that even the geometrical patterns on a web page can induce a positive impression from users whereas previous studies mainly focused on human-shaped mimickers.
- Based on the results, we discussed how mimicry can be more exploited from the perspective of HCI.

To the best of our knowledge, this is the first approach to introducing the mimicry effect in the browsing experience. In other words, incorporating emerging technologies, we paved the way in a scalable manner to practical applications based on a psychological effect. We believe that our approach provides new insights for the HCI community into the design of browser-based interactions.

2 BACKGROUND AND RELATED WORK

To situate our work, we first review articles on the mimicry effect, which was originally proposed in the field of psychology. Then, we cover previous studies investigating whether similar effects would occur in computer-mediated communication. We also review the existing techniques of designing interactive web pages to discuss the possibility of expanding the design space using the browser-based mimicry effect.

2.1 Mimicry

Mimicry was originally discovered to occur in face-to-face interactions. This phenomenon is the unintentional synchronization of nonverbal cues such as postures [32], facial expressions [27], speech characteristics [7], and mood [43]. The role of mimicry in human communication is understood to be a glue between social animals, creating rapport and affiliation with each other [37]. Chartrand et al. coined the term *chameleon effect* to conceptualize the effect of mimickees feeling positively toward mimickers [11].

Since then, many studies have been conducted to examine the mimicry effect in various human-to-human interactions [12, 56]. For example, van Baaren et al. showed that restaurant servers who mimicked a customer's order received significantly larger tips than those who did not [55]. William et al. discovered mimicry increases trust in a deal-making situation [39]. Sanchez-Burks et al. replicated the effect in a business interview by comparing the question–answer response latency and the interview performance, which was rated by human resource experts, between interviewees who were mimicked by the interviewer and those who were not [47].

Previous studies also showed that the appearance of the mimicking stimuli is not necessarily the same as that of the mimickee. Catmur and Heyes conducted an experiment in which participants were asked to lift a hand or foot randomly while watching a video of a hand and foot on a screen [9]. They found that the participants responded positively to the mimicking movements when the foot on the screen lifted when a participant lifted a hand and when the hand on the screen lifted when a participant lifted a foot. Kumazaki and Takeuchi even suggested that a similar effect occurred when the mimicker's appearance was a simplified stick figure [36].

2.2 Mimicry in Computer-Mediated Communication

Based on the above studies, Bailenson and Yee introduced mimicry into computer-mediated communication [3]. They explored the effect of mimicry in immersive virtual reality through the interaction between participants and embodied artificial agents. While the participants watched a persuasive speech delivered by an agent, their head movements were captured using an orientation-tracking sensor. Then, the researchers compared two types of agent behavior: one agent mimicked the participant's head movements with a 4 seconds delay, and the other used the other participant's recorded movements. As a result, the mimicking agent was viewed as more persuasive and likable than the agent using recorded movements.

From that moment, the mimicry effect was confirmed to occur in various human-to-nonhuman interactions. Previous studies have shown that the mimicry of head movements increases rapport [23] and trust [57] with virtual agents. Some studies have also been conducted to examine the positive effect of mimicry using robot-based interactions [17, 49, 52].

Despite the large amount of work that has been conducted to produce the mimicry effect computationally, there are few studies that incorporate this effect into user interface design outside of virtual reality environments or robot-based communications. This can be attributed to the scarcity of means available to capturing human behavior such as head movements. For instance, most of the previous work used a head-mounted display, an externally attached magnetic motion tracking device [23, 57], or an infrared sensor [17, 49, 52, 53], and this prevents the creation of a scalable application of mimicry.

In this respect, our study first examines whether we can implement the mimicry effect in a popular platform (e.g., a web browser), requiring no additional sensors. By bringing the psychological effect into day-to-day situations, we anticipate that many promising applications in human–computer interaction will arise.

2.3 Interactive Browsing Experience

In the age of the Internet, billions of people consider web content to be part of their daily lives, and thus, enabling interactive browsing experiences has been an important topic in the HCI community [19]. Currently, with the rise of JavaScript-based client-side interactivity, many interactive designs have become common.

A common strategy is to exploit the user's mouse behavior, such as moving the background pattern in accordance with mouse movement to improve user experience. For example, parallax scrolling is a popular technique that moves background images on a web page more slowly than foreground contents. It is confirmed to induce an illusion of depth on a two-dimensional site [16] and correlates user attitude positively with the contents [58].

Another emerging approach is leveraging the user's gaze data [40]. Originally, this input modality was often adopted for user-to-display interactions such as scrolling text, continuous attribute display [30] and moving cursors [61]. Based on these studies, there have been several proposals for integrating gaze data as an input modality [35, 42]. Some studies leverage gaze information not for pointing or selection but for augmenting passive browsing experiences, such as prioritizing loading objects based on gaze direction to improve user-perceived latency [31].

Regarding smartphones, a tilt sensor is also available to capture a user's behavior. For example, some web pages move part of their contents in accordance with the tilting of the device. In fact, it has been confirmed that tilting can assist not only the targeting gestures [10] but also various interactions in combination with tapping [18].

Here, we hypothesize that browser-based mimicry can expand the design space of interactive browsing experiences by exploiting a new input modality outside of cursors, gazes, and tilting. To this aim, our second experiment investigates the impression on a user of a web page whose background pattern implicitly mimics the user's head movements, anticipating a preferable impression. We recognize that some previous works have exploited the head movements as a new input modality [4, 60]. In contrast to previous studies that often focused on a user's active inputs, such as selecting or scrolling, our approach exploits indirect mimicking feedback that may not be recognizably appreciated, and this may widen the range of interactive browsing experiences.

3 EXPERIMENT I: MIMICRY EFFECT IN WEB BROWSERS

The goal of this experiment was to verify whether the mimicry effect can be induced on a web browser interface without the use of external sensors. We essentially followed the experiment procedure of Bailenson and Yee [3], which originally introduced the computational approach for mimicry. We conducted a between-subjects experiment on two groups (mimicked and recorded) to investigate the impressions induced by the mimicking agent, which delivered a short speech.

3.1 Implementation

We constructed the experiment environment as a standalone web application. We used Jeeliz[1] to capture the head movements of users using a webcam in a web browser. In detail, the image captured by the webcam is fed to a neural network to estimate the pose of the user's head. Here, because the network runs on a GPU using the WebGL API, we can capture the pose in real time. Then, the captured movement is reflected in a 3D agent, which is rendered using three.js[2].

3.2 Participants

We recruited 21 participants, ranging in age from 21 to 65, three of which were female. They were recruited using word-of-mouth and online communication in a local creator community in which over 100 university students gather. Here, all participants reported that they are or used to be university students. They received approximately $3 in local currency as compensation for approximately 15 minutes of participation.

We randomly divided the participants between the mimicked and recorded groups. As a result, there were 12 participants (1 female) in the mimicked group and 9 participants (2 female) in the recorded group. Two of the participants from the mimicked group detected that their head movements were copied, which is described later in this paper.

3.3 Procedure

At the beginning of the experiment, the participants were presented with a web page containing a research consent form and a brief description of what would be shown in the experiment. Then, they proceeded to the calibration of the computer's audio and camera, and a webcam placed at the top of the computer screen began capturing their face. When they confirmed that it was tracking their face correctly, they began an experiment session.

During the session, a 3D agent delivered a presentation in English about a plan to raise school fees at an unknown university and listed several reasons. The speech content was based on Maricchiolo et al. [41], which evaluated the role of hand gestures in persuasive speech using a stimulus in Italian. In our setting, we played the recorded voice giving the presentation, which lasted 103 seconds. After the recorded voice finished, the participants were redirected to a questionnaire page.

During the questionnaire, they evaluated the agent using the same subjective measures and open-ended questions as used in Bailenson et al. [2]. They were first asked their agreement with 4 statements about the proposal and 12 statements on the agent's impression on them; the questionnaire used a fully labeled 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Then, they were presented with four open-ended questions regarding their experience, the interaction, and the presenter's movements, such as *"Was there anything unusual about this interaction?"*

3.4 Setup

A setup of the experiment is shown in Figure 2. The participants were seated at a table in a conventional office-like environment. We used a 15-inch laptop (2880×1800 pixels) for displaying the agent's presentation. We used its built-in webcam, the 720p FaceTime HD camera, to capture each participant's head movements.

[1]https://jeeliz.com/

[2]https://threejs.org/

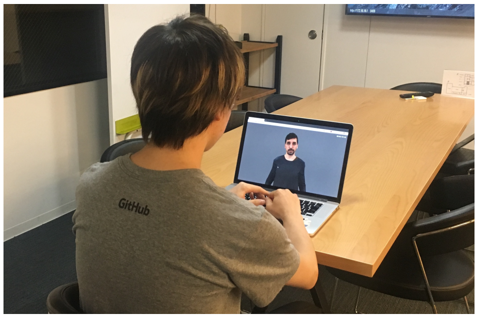

Figure 2: Example setup of the experiment. The participants watched the presentation in a web browser without being attached to external sensors.

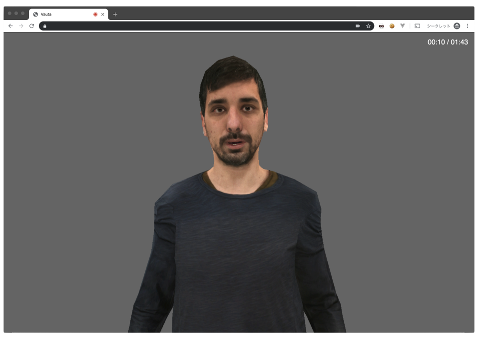

Figure 3: Actual interface used for the experiment. For the participants in the mimicked group, the agent[3]replicated head movements at a 3 seconds time delay.

3.5 Design

Our experimental design included a single between-subjects variable, that is, the agent's behavior (mimicking or recorded). For the mimicked group, the head movements of the agent followed the participant's head movements at a 3 seconds time delay because previous studies showed that mimicry usually occurs within 3 to 4 seconds delay [56]. For the recorded group, the agent's head movements exactly copied the movements of the previous participant in the mimicked group, and thus, different types of movements were shown to different participants. Note that this design is following previous studies [3, 22], considering that presenting previously recorded movements is much easier than generating human-like movements computationally. In both groups, the agent's lip movements were driven by the amplitude of the recorded voice.

Figure 3 shows the appearance of the 3D male agent used in this experiment. We did not use a female agent because the original study by Bailenson and Yee [3] reported that the gender variable was shown to have no significant effect on the impression made by the agent.

3.6 Measures

3.6.1 Effectiveness of the Mimicry. In the same manner as in previous studies [2, 41], we applied a factor analysis with a promax (oblique) rotation to the responses to the 16 subjective measures in order to simplify analysis. Next, factor scores that corresponded to the extracted factors were estimated using the linear regression method [54], which produces the standardized score with a mean of zero [14]. We then examined the effect of the mimicry by performing Welch's t-test on the factor scores.

Our hypothesis was the same as that of Bailenson and Yee [3]. In other words, we expected that the mimicking agent would be more favored and receive higher scores than the non-mimicking one.

3.6.2 Head Movements. We recorded the participants' side-to-side head movements. Although Bailenson and Yee [3] recorded the movements at approximately 12 Hz using an attached orientation-tracking sensor, our sampling rate was approximately 30 Hz, which was the average performance of the head movement estimation we observed using our laptop. We then compared the maximum value (in degrees) of rotation from the front-facing position between the mimicked and non-mimicked participants using Welch's t-test in the same manner.

Here, the hypothesis was the same: We anticipated a larger rotation for the recorded group than for the mimicked one, as mimicking was expected to improve the visual attention that is thought to be negatively correlated to the variance of the head movements.

3.6.3 Mimicry Detection. To exclude the participants who noticed the mimicry, we followed the procedure of Bailenson and Yee [3]. Two raters read the responses to the four open-ended questions of all participants with no information on participants' assigned groups and labeled whether they believed each participant detected mimicry. As a result, the raters regarded the same two participants (male) from the mimicked group as detecting mimicry, and thus, they were removed. The final number of participants in the mimicked group was 10, whereas that in the recorded group was 9.

3.7 Results

3.7.1 Effectiveness of the Mimicry. From the factor analysis of the subjective measures, three factors explaining 74.5% of total variance were extracted. Each variable from these measures was assigned to the factors for which they had the highest loadings, as shown in Table 1.

The first factor can be described as *favorable*, which included the measures on *likable*, *friendly*, *warm*, *approachable*, *credible*, *trustworthy*, *needed*, and *modest* (Cronbach's $\alpha = .93$). The second factor can be described as *knowledgeable*, which included *informed*, *honest*, *valuable*, *competent*, and *sincere* ($\alpha = .83$). The third factor can be described as *persuasive*, which included *agree*, *interesting*, and *workable* ($\alpha = .83$).

The means and standard deviations of the extracted factor scores are presented in Table 2. We found that mimicry increased the factor score of *favorable* and *persuasive* significantly ($p < 0.05$) compared to the recorded group. However, there was no significant difference in the factor score of *knowledgeable*.

Although the obtained factors are different from those in Bailenson and Yee [3], the results share certain aspects with their report. In detail, they found that mimicry had a significant effect on the ratings of the impression of the agent but not of the content of the presentation. Similarly, our result suggests a closer relationship

[3]This 3D model is distributed by https://sketchfab.com/xavioromi under CC BY 4.0.

Table 1: Factor loadings for the 16 subjective measures on the three extracted factors.

Measures	Factors		
	Favorable	Knowledgeable	Persuasive
Likeable	0.90	0.73	0.48
Friendly	0.90	0.73	0.56
Warm	0.86	0.59	0.60
Approachable	0.85	0.64	0.43
Credible	0.83	0.68	0.41
Trustworthy	0.80	0.74	0.46
Needed	0.78	0.40	0.63
Modest	0.68	0.23	0.41
Informed	0.48	0.86	0.16
Honest	0.56	0.81	0.60
Valuable	0.75	0.78	0.72
Competent	0.38	0.72	0.35
Sincere	0.60	0.69	-0.06
Agree	0.69	0.53	0.85
Interesting	0.42	0.27	0.84
Workable	0.72	0.74	0.81

Table 2: Effects of the mimicry on the extracted factors.

Factor	Mimicked		Recorded		p-value
	Mean	SD	Mean	SD	
Favorable	0.52	1.22	-0.47	0.41	0.044
Knowledgeable	0.41	0.98	-0.37	0.91	0.088
Persuasive	0.47	1.01	-0.43	0.82	0.049

Table 3: Effects of the mimicry on the head movements of the participants.

	Mimicked		Recorded		p-value
	Mean	SD	Mean	SD	
Max rotation	13.6	6.8	25.6	11.7	0.019

between mimicry and the impression measures than the content measures.

3.7.2 Head Movements. We also examined the head movements of the participants and analyzed the effects of the mimicry on their magnitude. The means and standard deviations of the maximum rotation in degrees are presented in Table 3. As we expected, the participants in the recorded group showed a larger rotation than the participants in the mimicked group, which suggests that the mimicked participants kept their attention to the agent.

From these results, we conclude that the positive effect of mimicry is transferable to a browser-based interaction with an agent without depending on external sensors. In particular, we confirmed this effect of drawing a favorable impression from and the attention of participants based on their subjective responses and head movements.

4 EXPERIMENT II: APPLICATION EXAMPLE OF USING BROWSER-BASED MIMICRY

As we confirmed the existence of the mimicry effect in the browser-based interaction, we conducted a second experiment to explore the possibility of exploiting it in practical applications. Here, we developed a gimmicked web page that mimics a user's head movements in its background patterns, hypothesizing that the mimicry prompts the user to have a favorable impression of the web page. We conducted a between-subjects experiment on three groups (no-background, mimicking-background, and recorded-background).

4.1 Implementation

In the same manner as the first experiment, we used Jeeliz for capturing the head movements of users on a web page. In this case, movement is reflected not to the agent but to the background pattern of the web page. We modified jquery.particleground.js[4], a popular jQuery plugin that offers parallax scrolling [16] against mouse movement using dynamically animating patterns in the background. Our implementation animates the background pattern according to the head orientation of the user in yaw and pitch directions instead of the mouse position in x and y directions. We note that the background pattern is fixed to the screen and does not follow the mouse scrolling. A sample transition with head rotation is presented in Figure 4.

4.2 Participants

Using the same approach as the first experiment, we recruited 37 participants, ranging in age from 21 to 65, of which nine were female. Only two participants had participated in our first experiment at least two weeks before. We note that they had not noticed the mimicry in the first experiment. The participants received approximately $1 in local currency as compensation for approximately 5 minutes of participation. After a random assignment, there were 12 participants (3 female) in the no-background group, 12 participants (4 female) in the mimicking-background group, and 13 participants (2 female) in the recorded-background group.

4.3 Procedure

In the same manner as the first experiment, the participants first read and agreed to our research consent form. Then, following the calibration process, they accessed a web page that featured tourism information for Hawaii. We asked them to explore the web page freely but carefully and to proceed to the questionnaire form when they were satisfied.

In the questionnaire, we asked them to rate their impressions of the web page using three questions, which are described in Section 4.5. The participants answered these questions using a fully labeled 7-point Likert scale in our first experiment. In addition, they filled in one open-ended question: *"Please let us know anything you have found about the web page."*

[4]https://github.com/jnicol/particleground

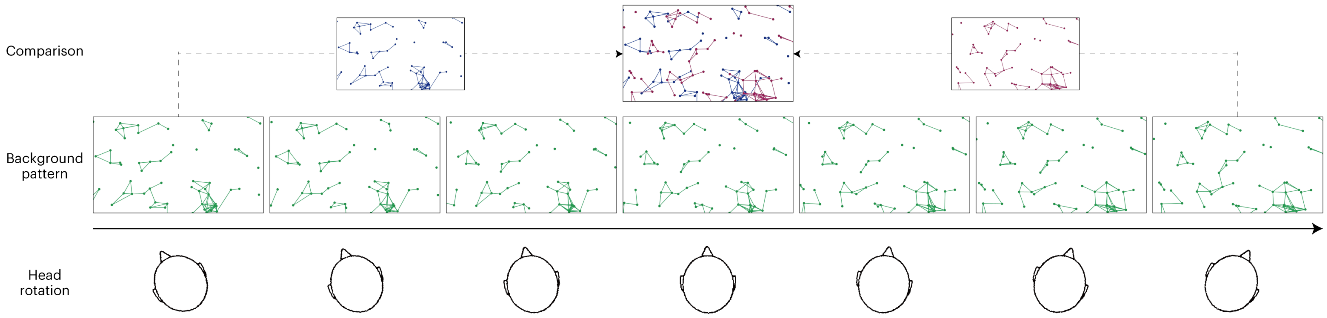

Figure 4: Example transition of the animating pattern in accordance with the head rotation of a user. The pattern was presented in the background of the web page during the experiment.

4.4 Design

The design included a single between-subjects variable (no-background, mimicking-background, and recorded-background). We used a similar setup as for our first experiment, that is, the background pattern of the web page followed the participant's head movements with a 3 seconds delay in the mimicking-background group. On the other hand, in the recorded-background group, the background pattern followed the previous participant's movements. We added the no-background group, which hid the patterns, in order to ensure that the pattern did not interfere with users' viewing of the web page.

Here, we paid attention to the fact that such moving background patterns can be annoying when applied to some types of websites, such as those requiring focus [51], although they are confirmed to be an attractive design practice in general [45]. Therefore, we designed the content of the web page so that participants would enjoy it without becoming nervous, just like articles found in everyday web surfing. In addition, it is desirable that visitors would stay in the web page for a certain amount of time, considering that previous studies often persisted the mimicking for at least 40 seconds [22]. Based on these points, we created a blog post listing five little-known tips about Hawaii in Japanese. We also embedded a short video[5] produced by the Hawaii Tourism Authority that lasted 30 seconds and introduced tourist spots. A screenshot of the web page is shown in Figure 5.

4.5 Measures

4.5.1 Effectiveness of the Mimicry. To examine the effectiveness of the browser-based mimicry, we used the following questions for the post-session questionnaire:

1. Do you agree that this web page is favorable?
2. Do you agree that this web page is knowledgeable?
3. Do you agree that this web page is well designed?

The first two questions correspond to two of the three factors that we extracted in the first study. The remaining factor of *persuasive* was not included because the content of the web page was not designed to persuade readers, and thus, it was not applicable. The last question was added to examine the effect of the perceived design quality on the responses to the previous questions. Here, these questions were presented in Japanese because all participants were fluent speakers. We then examined the effect of the mimicry among three groups using a Kruskal-Wallis test since the responses from the participants were on an ordinal scale and consisted of more than two groups.

Figure 5: Example interfaces of the web page[6] used for the experiment. For the participants in the mimicking-background group, the background pattern behind the content[7] followed head movements at a 3 seconds time delay.

[5] https://www.youtube.com/watch?v=CN84elB-zeE
[6] The lines in the background pattern are thickened for clarity.
[7] The images in this web page is distributed by https://www.flickr.com/photos/3059349393/ and https://www.flickr.com/photos/mark_i_geo/ under CC BY 2.0 license.

Table 4: Effects of the browser-based mimicry on the responses of the three questions.

Question	H	p-value
Favorable	11.094	0.004
Knowledgeable	2.839	0.242
Design	5.871	0.053

Table 5: Effects of the browser-based mimicry on favorableness.

Compared groups	U	p-value
No — Recorded	0.571	0.889
No — Mimicking	10.508	0.039
Recorded — Mimicking	9.937	0.039

Our hypothesis was that there would be a significant improvement in the *favorable* factor for the mimicking-background group compared to the recorded-background group. At the same time, we expected that the mimicking background pattern would be a feasible design approach, that is, at least maintaining the perceived design quality. Thus, it was hypothesized that there would be no significant difference in the design quality between the no-background group and the other groups.

4.5.2 Mimicry Detection. As in the first experiment, two raters checked the responses to the open-ended question, blind to the participant's assigned group. Consequently, both raters regarded one participant (male) from the mimicking-background group as having detected the mimicry. Therefore, we had 11 participants in the mimicking-background group after removing this participant.

4.6 Results

As presented in Table 4, the Kruskal-Wallis test revealed that the responses on favorableness were significantly different among the three groups ($p < 0.05$). However, we did not find a difference in the responses on knowledgeability, which matches the result of our first experiment. In addition, as we expected, there was no significant difference in the design quality regarding the existence of the background patterns.

Based on this result, we performed a Mann-Whitney test as a post-hoc analysis to examine the difference in each pair among the three groups regarding favorableness. Here, we used Holm's sequential Bonferroni procedure [25] to adjust the p-values in multiple testing.

As shown in Table 5, the participants in the mimicking-background group gave significantly more positive responses than those in the recorded-background and no-background groups. However, there was no significant difference between the recorded-background and the no-background groups. These results suggest that this positive effect is attributable not to the existence of the background pattern but to its mimicking movement.

4.7 Analysis

These results confirm that the background pattern did not interfere with the participants' viewing of the web page, since the existence of the background pattern did not affect their subjective evaluation of the design. In other words, although there was no significant difference in the perceived design quality, we found a significant improvement in favorableness for the mimicking-background group compared to the other two groups. These results indicate that mimicry in a pattern in the background was not appreciated as an explicit design component but may have implicitly improved the user's impression of the web page. This phenomenon empirically affirms our approach of utilizing the mimicry effect for augmenting browsing experiences.

However, we should note that this positive effect was discovered from the responses of the participants who did not detect the mimicry. In fact, the participant who noticed the mimicry provided the following comment after finishing the experiment:

> I realized that the background pattern was following my head movements. Then, I spent some time playing with this trick. As a result, I paid more attention to the background pattern than reading the content itself.

His comment implies that mimicry may distract the user's attention when it is noticeably implemented.

5 DISCUSSION

The primary goal of this study was to utilize the mimicry effect as a novel interaction technique in practical applications, and we conducted two experiments to examine a user's impression of a mimicker in the browser. In this section, we first discuss the novelty of the positive effect caused by nonhuman mimickers that we empirically showed in Section 4.7, along with a possible mechanism behind it. Next, we examine the limitations of the current study and concerns for future implementations so that our findings serve as a first step for practical applications. Finally, we discuss future areas of application to which we believe the proposed approach will contribute.

5.1 Effect of Nonhuman Mimicker

Although we confirmed that users responded positively to our mimicking web page, we should note that the mechanism for this phenomenon is not trivial. In particular, considering that previous studies in psychology or neuroscience have mainly investigated this effect involving a human confederate, the response to nonhuman mimickers such as geometrical patterns is not well investigated. This is due to the fact that unlike the case of mimicking by a human confederate, generating movements of a nonhuman object so as to mimic human movements in real time is hardly feasible without the help of computers, which leaves the mechanism behind this effect unexplored.

To account for our subconscious tendency to mimic another person's nonverbal behavior in social interactions, several studies in the field of cognitive neuroscience showed that this involves the activity of the inferior parietal cortex and premotor cortex [20], which is often referred to as the mirror neuron system [46]. Moreover, Wang and Hamilton revealed that spontaneous mimicry reflects a social top-down response modulation that is controlled by the medial prefrontal cortex [59].

In contrast, although many studies have confirmed the positive impression on a mimickee by a mimicker in various settings, as we discussed in Section 2.1, we have not seen an established cognitive model to explain these empirical results systematically. This can be attributed to the difficulty of measuring brain activity caused by spontaneous social interactions [21]. To infer possible cognitive models, Hale and Hamilton [22] reviewed previous neuroimaging results from various paradigms such as perception–action matching [29], self–other processing [13], and a reward system linked to prosocial behavior [34]. They consequently introduced a contingency model that suggests that the contingency between our actions and the world is intrinsically rewarding and motivating. In their theory, the mirror neuron system may be responsible for detecting this contingency, which was also empirically shown in some experiments [8, 24]. They suggested that this model can be one explanation for the positive responses to a mimicking agent whose appearance does not match that of the mimickee [9].

We speculate that the result of our second experiment could be related to this interpretation. In other words, based on the fact that the mirror neuron system responds to stimulus even if it is not human-shaped (e.g., a geometric object) [15, 46], the contingency model can explain the positive response to the mimicry by a nonhuman agent. We believe that the result of our second experiment, which has suggested users feel positively toward a mimicking geometric pattern in a web page, could provide new insight into the comprehension of the mimicry effect. In particular, our computational approach that enabled mimicking with nonhuman objects would be the first step for further in-depth investigations, such as measuring a mimickee's neural response to geometrical patterns using neuroimaging techniques.

5.2 Limitations and Concerns

As previously mentioned, further investigations involving a greater number and diversity of participants are desirable not only for understanding the mechanism of the mimicry effect but also for generalizing our results. For example, Zhang and Healey reported that they could not replicate the mimicry effect in an immersive virtual environment [63]. They suggested that the effect is not so robust that it would be possibly hindered by the uncanny valley effect, which can explain the discrepancy with our result of the first experiment in regards to the difference between full-body immersion and a laptop screen. In addition, Sanchez-Burks et al. found that the magnitude of the mimicry effect is affected by the cultural group of participants [47]. Though we followed previous studies for the delay time (3 seconds) in mimicking, as mentioned in Section 3.5, the effect can also be influenced by the length of the delay. Nevertheless, we believe that our result, along with future experimental explorations, would contribute to clarify the boundary of the situations that the mimicry effect works.

Regarding applications on the Internet, there is room for improvement. For example, the effect on a web page can depend on the type of content presented on the page, in the same manner as that moving background patterns themselves shows a low affinity for specific contents, which we mentioned in Section 4.4. In addition, as we discussed in Section 4.7, a user who detects mimicry can be negatively affected. detects mimicry can be negatively affected. In that respect, Bailenson et al. [2] compared three mimicry strategies mirroring exact movement (left was left), reversed movement (left was right), and axis-switched movement (left was up) during interaction with an avatar in a virtual reality environment. As a result, they concluded that the axis-switched mimicry showed a significantly lower detection rate, while the positive effect of the mimicry was preserved. We may be able to integrate such a strategy to avoid detection, although the detection rate in our second experiment was relatively lower than in their study.

The privacy of users can also be an issue for applications. Collecting user behavior using sensors such as webcams naturally raises concerns about privacy [44]. Almost all web browsers indeed deny web applications from accessing webcams unless a user explicitly allows access. In addition, Machuletz et al. reported that approximately 36% of their interviewees used a webcam cover to avoid unauthorized access to their cameras [38].

One consolation is that our approach captures the movements of users within a web browser using client-side scripts. Thus, there is no necessity of sending behavior information to a remote server. Considering that the advantage of using a camera on the client side has been shared in multiple studies, including [31], the access control of webcams in browsers can be expected to be relaxed on the condition of denying remote communication in the near future. Still, further consideration is required to develop a reasonable explanation for users while preventing the detection of the mimicry.

5.3 Application Areas

Regardless, the proposed approach of yielding the mimicry effect on web pages may have a large impact regarding practical applications. For example, corporate websites can use this mimicry, expecting that their brands are favorably received by visitors. Furthermore, many websites would embrace this approach if the existence of its positive effect was also confirmed by a decision-making process in the same manner as the mimicry in human-to-human communications, such as increasing server tips [55] or making a successful deal [39]. Corresponding to these studies, there is a possibility that commercial websites increase their revenue with the aid of the proposed browser-based mimicry.

Regarding this, we note that the proposed approach would open up its application possibilities through the simpleness of its implementation. As explained in Section 4.1, it is based on the combination of the popular libraries, and thus, web designers can easily integrate it in the same manner as existing design techniques mentioned in Section 2.3. Since Jeeliz, the JavaScript-based library we used to capture head movement, uses a model file with only 1.4 MB and runs on WebGL, our implementation would be compatible with most browsing devices. In addition, this programmable integration allows context-sensitive customization, such as activating the mimicry only at the timing of the first visit, which would impact the subsequent impression, for the purpose of reducing the possibility of being noticed by users.

We would like to emphasize that the areas of application are not limited to conventional websites. Although further investigations are needed, our results of realizing browser-based mimicry and confirming its positive effect in a scalable platform will have a major impact on computer-mediated communication, which is facing a soaring demand due to COVID-19. For example, our second experiment implies that, in video calls, animating the background patterns based on the estimated head movements of the counterpart, as if it were a new virtual background in Zoom, possibly enriches the communication. While a similar approach was proposed by Suzuki et al. [53], which applied an image transforming technique for editing facial expressions by a compulsion to offer the mimicry effect, such a computational morphing of human appearance is not riskless because it can result in an inconsistency between nonverbal behavior and conversation content. In this respect, the proposed approach of just changing the background patterns rather than transforming user appearance would be another suitable alternative in regards not only to the consistency but also to its scalable implementation.

In addition, emerging avatar-based communication would be able to benefit from our proposed approach. We note that, as is known to provide live-like sensation and interaction experience [48], avatar-based communication has been introduced in many situations such as vlogging (i.e., posting videos or broadcasting on YouTube) avatar called VTuber [28], medical communication avatar [48], and interview training avatar [26]. For example, while current VTubers reflect the motions of the human actors, they can potentially induce positive impressions using our proposed approach. Since our method runs in a web browser alone, it is possible to change the motion of VTubers to mimic each user in real time. Then, using computational methods to detect the behavioral cues of humans [1, 5], we can dynamically blend the original motion and the mimicking motion, such that only small subconscious cues of the user are mimicked but the overall body movements roughly follow the actor's movements.

Moreover, the proposed approach is applicable as a design practice for many devices other than laptops since it requires only a single camera. For instance, even smartphones can change the background animation of its home screen following a user's head movements. Given that various animation patterns for loading screens have been considered in TV and other devices [6, 33], it is also conceivable to apply mimicry to the background of a loading screen in such devices to offer better user experience while a user waits.

6 CONCLUSION

In this study, we have presented a novel browser-based interaction leveraging the mimicry effect. Through two experiments, we showed that the proposed approach of mimicking a user's head movements could induce a favorable impression not only in the case of an avatar-based communication but also through a geometrical pattern presented in the background of a web page. We would like to emphasize that current applications of the mimicry effect are mainly confined to virtual reality environments or robot-based communications due to a dependency on physical sensors. In contrast, since our approach is implemented in a scalable manner, various applications, including but not limited to augmented browsing experiences, can be expected, which would introduce a new approach of human–computer interaction.

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