P/REFERENCES OF DESIGN

IMMERSIVE DESIGN THROUGH SYNCHRONIC PROCESSES BETWEEN BODY AND SPACE.

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ABSTRACT | The diffusion of digital and digitized environments enables the increase of possible readings of space. At the same time, the development of wearable devices enables the body to multichannel interface. The research is inscribed in scientific and design reflection that explores the relationship between digital information and the human body. Through multi-channel modality, the scope of the project can act cross-modality on perception and cross-media on information. Following the development of research on the channel of touch and the technical possibilities related to the development of tactile communication on the body's surface, the research chose to carry out an experiment dedicated to the relationship of this sense with sight. We then introduce the phenomenon of rhythmic synchrony as a perceptual tool for creating a sense of immersion and attention management. After defining the properties of a cross-modal and cross-medial rhythmic signal, two experimental tests were carried out to verify the signal's effectiveness on perception. The test results show that cross-modal rhythmic stimulation has a good ability to direct users' choices. The experimentation lays the foundation for further research in cross-modal synchrony as an element of engaging people and supporting decision-making and attention processes in digital information-dense environments. Subjects' choices to synchrony effects highlights the opportunity for applications designed to increase the connection between the body and the interface in immersive experiences.

1. Introduction

In the contemporary context, in which the presence of digital technologies is becoming increasingly pervasive in real and virtual spaces, the physical and cognitive relationship aspects between the body and artifacts becomes an important element of interaction and communication processes. In this context of transformation, the body in its perceptual and motor complexity increasingly becomes a direct interface to digital services (Zannoni, 2022). The interface body can communicate through bidirectional processes of information exchange with the space it relates to and crosses in the architectures in which it lives in its daily life. These transformative scenarios, in which a pervasive relationship between human and machine emerges, are gradually introducing new design visions that have been identified with the term *Ubiquitous Computing* since the late 1990s (Weiser, 1999). In these, the quality of the relationship between tools and spaces augmented through the integration of digital services often results from the multisensory characteristics of the designed interactive systems. Spaces and devices that offer a digital experience increasingly have quality objectives proportionate to their ability to dialogue with the body using multichannel communication. This is also demonstrated by the fact that the research and market for technologies is increasing year by year and the amount of projects that take into account multisensory aspects in interaction processes. The rapid growth toward the integration of digital technologies in everyday spaces highlights on the one hand the possibilities of hierarchizing more of the information sent to people, and on the other hand it allows for imagining systems capable of making information more accessible. The museum setting is a relevant example on how multichannel information can be articulated by meeting needs related to the perceptual difficulties of categories of users (Eardley, Mineiro, Neves, & Ride, 2016).

An increasing number of digital environments are coming into common use. Examples are places designed for learning complex procedures (Sowndararajan, Wang, & Bowman, 2008) or for the health care setting (Bateni, Carruthers, Mohan, & Pishva, 2024). Frontier of the field that investigates multichanneling in partial or full immersion scenarios is that of e-sports and simulators. These applications aim to reproduce with high quality standards real experiences in controlled and distant spaces. In recent decades, multiple wearable or hand-held devices that integrate haptic perception have been experimented with to simulate real pressor experiences on our bodies. These experiments have been introduced into multiple commercial products becoming an established media channel recognizable by users (Lederman & Klatzky, 2009). The field of gaming and simulation are the most popular commercial vectors of these trends. In support of immersive design, two concepts support reflections on how enabling and emerging technologies should be more investigated from a multisensory perspective: cross-modality and cross-mediality.

We can consider cross-modality in this context as a mechanism through which sensory information is processed and decoded by the brain by exploiting features related to spatial proximity and synchrony (Balconi & Carrera, 2008). The convergence of congruent and simultaneous stimuli between the senses allows for the identification of recursive patterns that the body reads based on its prior experience and in an automatic manner. From the point of view of the design domain, this notion allows us to understand how important it is to consider the design of experience as a system where the body is always involved with all its parts and that any sensory information has repercussions on the entire perceptual and cognitive system.

At the same time, the cross-media introduced in the 1970s in the literature starts from the assumption proposed by Marshall McLuhan (1964), in which media are a translation of ourselves and an extension of our prosthetic system. With respect to this assumption, in relation to the contemporary technological debate, if we consider that most adult people use a smartphone on a daily basis to communicate and connect to the web, it is plausible to argue that these devices are an extension of our body. Media systems thus establish a symbiotic relationship with the body and modify the human perceptual and communicative capacity. Cross-mediality becomes evident in the integration with devices and media from the moment we have "hooked up" to the network and its services, speeding up more and more the processes of communication at a distance (Bauman, 2002) and delegating part of our memory to these devices (Bagnara, 2006; Bannon, 2006; Flusser, 1990). Concerning the evolution of the tools available to humans in the processes of relationship between interactive systems, regardless of whether they are artifacts or spaces, it becomes crucial to investigate the role of haptics not only from the perspective of perception but in relation to design scenarios in the field of design. When we do not have direct human-machine relationship action mediated by an interface, in many cases the modes of relationship are naturally configured by activating automatic and uncontrolled cognitive processes. Tactile vibration and recognition of pressure rhythms fall into these case histories becoming interesting areas in the development of innovation in both real space design and emerging extended reality (XR) technologies.

2. The Relationship Between Haptic Languages and the Body

The sense of immersion and emotional involvement of people are among the aims of those who design digital or digitized environments. Among the characters that support these goals, multichannel information is an effective tool for hierarchizing content over time and providing feedback that increases the quality of control of the proposed scenario. In digitized environments involving more than one person, the channel of touch shows optimal qualities to increase the sense of immersion and emotional involvement in the experience. Acting on the surface of the body, thanks to an established development of wearable devices (Zeagler, 2017), the touch channel is distinguished by the quietness and invisibility of messages; these allow a high level of privacy to be preserved for the people receiving them (Jones & Sarter, 2008). Finally, the tactile channel, under conditions of sensory disability, can support perception by integrating information on the body surface (Shull & Damian, 2015).

The tactile channel can be used for complex information thanks to the diversity of stimuli it is capable of collecting-pressure, vibration, temperature-and the variations by which the same can be modulated-intensity, frequency, rhythm, pattern, symmetry with the body.

The complexity of haptic languages is further powered by the correspondence of the stimuli delivered with people's previous sensory experience. Indeed, research indicates greater perceived pleasantness in stimuli such as pressure than vibration (Pohl, Brandes, Ngo Quang, & Rohs, 2017), which is more foreign to the body's experiences in the world. The perceptual relationship of haptic messages on the body, however, has not only obvious potential with respect to the composition of messages on the surface; in fact, the literature shows how the use of haptic patterns in synchrony to other messages can support comprehension of written communication (Rovers & van Essen, 2004) and have emotional effects on receivers (Baumann, MacLean, Hazelton, & McKay, 2010; Koch, Fuchs, & Summa, 2014).

The types of information delivered through human-machine haptic communication is broad, as is the complexity with which languages can be constructed. To create codes that are recognizable by the human body, some research uses patterns of vibratory stimuli called *Tactons* (Brewster & Brown, 2004; Brown, Brewster, & Purchase, 2006; Brown & Kaaresoja, 2006; Brown & Kaaresoja, 2006; Barralon, Ng, Dumont, Schwarz, & Ansermino, 2007); others use patterns of pressor stimuli called *Pactons* (Zheng & Morrell, 2012). Finally, others use mixed systems of stimuli that alternate or work simultaneously (Kim, Castillo, Follmer, & Israr, 2019).

More complex codes ambition to tactually translate precise letters or phonemes (Enriquez, MacLean, & Chita, 2006). Other studies, on the other hand, aim to compose semantically simpler information and use stimuli to induce the body to react consciously or unconsciously or to suggest behaviors in space. In particular, several studies emerge in this regard that exploit haptics to support orientation in space through direction signals delivered in the sole of the foot (Frey, 2007; Velazquez & Pissaloux, 2014). An interesting solution has been studied in the automotive field to communicate the presence of cars in vehicle blind spots through haptic signals delivered on the surface of the steering wheel (Ploch, Bae, Ju, & Cutkosky, 2016). Previous studies by the authors show how it is possible to exploit haptic rhythmic variations to draw human attention to specific points on a pathway (Dall'Osso, 2021) or use a rhythmic pressor signal to unconsciously shift the body's center of gravity forward or backward at a given time (Dall'Osso, Zannoni, & Licaj, 2022). In all the haptic languages recalled in this concise examination, the rhythmic component plays a primary role in structuring sensory qualities. In his studies on form and figuration Paul Klee names touch among the senses that have the capacity to recognize rhythm consciously (Klee, 1959) or unconsciously. People have a habit of rhythmic perception that is consolidated from the body's earliest experiences in the world and then refined over time. Human reactions to the presence of rhythm are natural and cross motor, social and perceptual behaviors. Rhythmic entrainment is, for example, one of the most studied mechanisms of the human-rhythm relationship. Rhythmic entrainment occurs when the body, in the presence of a specific rhythmic stimulus, changes its behavior unconsciously and tends to move closer to that specific rhythm. Rhythm entrainment is well known in the relationship between movement and hearing so much so that studies and smartphone applications show how certain music can modify movement performance (Moens, van Noorden, & Leman, 2010; Moens, 2018) or generate feelings of calm (T. Azevedo et al., 2017). Thus, rhythmic entrainment can be said to be a natural human tendency to seek synchrony with a perceived external rhythm in the surrounding environment or people in proximity.

In the technological-digital domain, the sense of touch associated with synchrony effects is evident in numerous commercial products. Primarily, these are vibration actuators used inside phones and smartphones that are activated in synchrony with the ringtone to reinforce human attention-getting. Similarly, joysticks use vibratory systems to communicate to players sensations related to the scenario proposed in the video monitor. The evolution of devices related to digital sports shows in the contemporary the highest degree of complexity related to the use of haptic stimuli. Dedicated e-sports workstations, in fact, use diegetic or mimetic interfaces (Calleo, Dall'Osso, & Zannoni, 2023) where haptic stimuli synchronized with the video or VR experience increase the sense of immersion. This effect is achieved by stimuli that go to characterize digital elements and by the synchrony between haptic feedback and body movements poised between real and digital space.

In the product sector dedicated to private homes, two interventions on the sofa object that use haptics in a different way in sync with video are worth mentioning. The first is the *Miliboo smart sofa*[1], a sofa with a grid of vibration actuators, speakers and RGB lights integrated into the seat. Through the multichannel system, the sofa offers sensations synchronized to the video experience that is present on the television. A less recent project is *Immersit sofa*[2] (2017), a platform on which to place the feet of a generic sofa. The platform, thanks to motion video conversion software, inflates and deflates by moving the sofa on the three Cartesian axes. The resulting effect is a home station that moves in synchrony with the digital movie or game, causing a strong sense of immersion in the user. Thus, in the digital environment, synchrony is an effect that causes a strong sense of immersion and allows the user to perceive details of scenarios with a sense of reality. Following the concept of cross-modality, the synchrony proposed by the stimuli of digital devices has effects that cut across the entire experience and act on both conscious and unconscious levels.

The literature review did not highlight the design use of video-aptic synchrony for specific environments. Imagining technological applications related to *Ubiquitous Computing* contexts, it seems evident that the human body needs the development of tools to support attention and choices among multiple proposed interfaces. The potential of the rhythmic component as the basic structure of a cross-modal, cross-media language becomes the focus of the present research, particularly in the dimension of the subject of cross-modal synchronic information.

3. Cross-Modal Rhythmic Synchrony for Attention Activation

Within the problem field circumscribed in the introduction and following the review of scientific literature, the research focuses on the potential of rhythmic synchrony as a tool for supporting spatial attention. This, within current and future scenarios in which the human body is immersed in VR scenarios or *Ubiquitous Computing* and AR environments. The synchrony investigated by the research is cross-modal and cross-media.

[1] https://www.miliboo.com/smart-sofa.html

[2] https://www.kickstarter.com/projects/423274566/immersit-awesome-motion-and-vibration-device-under

Cross-modal synchrony refers in the coherent connection between two stimuli on different sensory channels, sight and touch. Cross-modal synchrony is activated through a coherent rhythmic message between the video present in the space and the vibratory signals sent on the surface of the person's body. With the aim of generating clear answers that can be a tool for future research advances, two tests were designed and conducted. In the tests, the objective was to determine the effectiveness of rhythmic synchrony in influencing a choice with or without disruptive elements. Repetition of the tests then aimed to understand whether prior experience can help in understanding synchrony.

Further objective of the research is to identify application possibilities related to the use of cross-modal and cross-media rhythmic synchrony with respect to wearable or body-contact devices under conditions of use.

4. Experimental Tests

In order to assess the quality of synchronic cross-modal rhythmic stimulus, two test protocols were designed. A total of 20 people ranging in age from 22 to 37 years participated in these. None of the people had apparent perceptual problems in the sense of touch and vision. A proportion of 65 % women and 35 % men took part in the test. Of these testers, 18 said their dominant hand was right-handed, 1 left-handed, and 1 claimed to be ambidextrous. The tests were given to individuals pertaining to the subject area of design and trained in visual communications. None of the subjects involved had been previously introduced to synchronicity issues.

At the end of the test, some information about the subjects' prior experience was collected. Specifically, it was found that the majority of testers (85%) had experience related to the study of music and almost all (90%) had no experience related to wearing wearable devices using vibrotactile feedback. Responding to how they perceived vibratory feedback on a Likert scale of 1 to 5 (1 pleasant, 2 acceptable, 3 mildly irritating, 4 irritating, 5 unbearable) the testers averaged a value of 1.9.
The tests were conducted in a quiet environment with no moving visual stimuli in the testers' field of view. Before the test, subjects filled out an anonymous form with some data about themselves -gender, age, dominant hand-. With the aim of having more involvement in the experience, each tester was told that they would receive a small gift (chocolate bar) at the end of the experiment.

The subjects involved were made to sit at a table on which was a hand control with two buttons (Fig. 1), one on the right and one on the left. At 1.5 meters in front of the subject, a large screen was placed for the testers to look at during the test. Before the tests began, subjects were made to wear two wristbands, one on each wrist, with a small vibrator on the inside of the wrist.

The system was implemented using an Arduino Nano 33 BLE Sense board and the Processing 4 programming language. The decision to use Arduino and Processing was motivated primarily by the flexibility and accessibility that these platforms offer for interfacing with physical sensors and actuators. The visual experience was designed with modularity and flexibility so that it can be adapted and used for further testing and allows the choice of shape, speed, direction of perceptual input, intensity of the vibratory stimulus, and phase duration.

The software allows signals to be sent to the Arduino board via serial to synchronously activate the connected vibro-motors. In addition, the system allows the physical button choices of the testers to be read and the milliseconds used to be recorded (we have indicated 100 milliseconds in the choice as a “false start”).

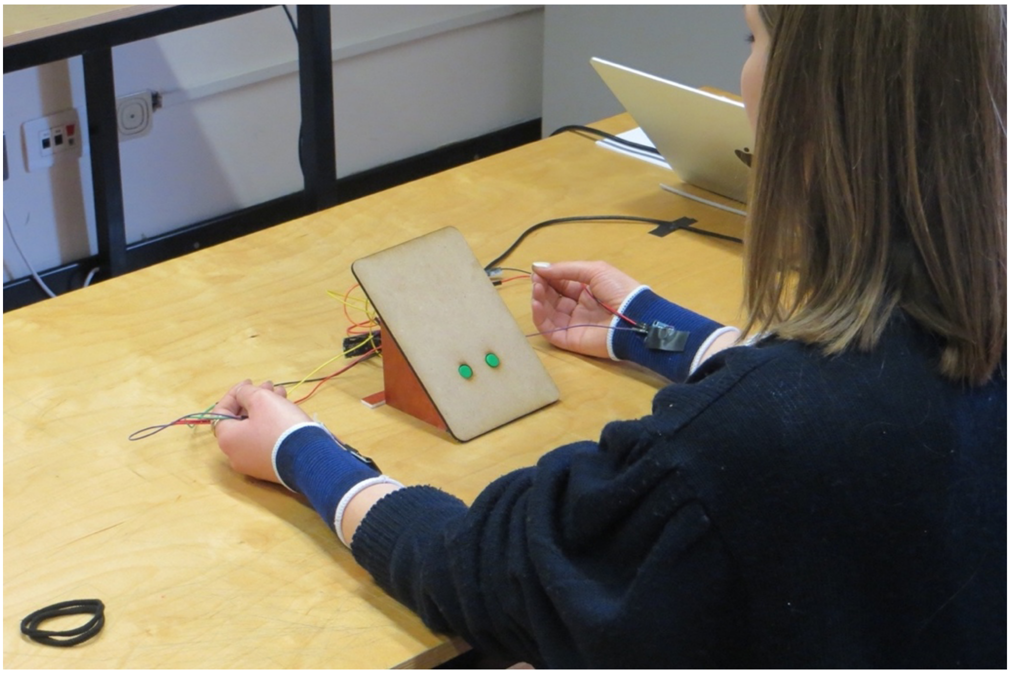

Figure 1. Detail of the prototype.

The objective of the tests (Fig.2) was to verify the effectiveness of rhythmic cross-modal signals to guide the testers' choice. To do this, the testers wore two wristbands with piezoelectric vibrators sewn into the inside of the wrist. In the first test (Fig.3) the vibrators send an identical and simultaneous rhythmic signal on the two wrists. During the test, subjects are asked to watch a video on which two identical circles are moving with the same animation but at two different rhythms. The rhythm of movement of one of the two circles is in sync with the vibration delivered on the tester's wrists (Fig. 4). The test has a duration of 20 seconds, and before the time runs out, the tester has to choose via a button one of the two circles. A countdown timer was introduced in the center of the screen so that subjects would be aware of the remaining time. The test was repeated twice in sequence for each subject. The second time the position of the circles on the screen was reversed.

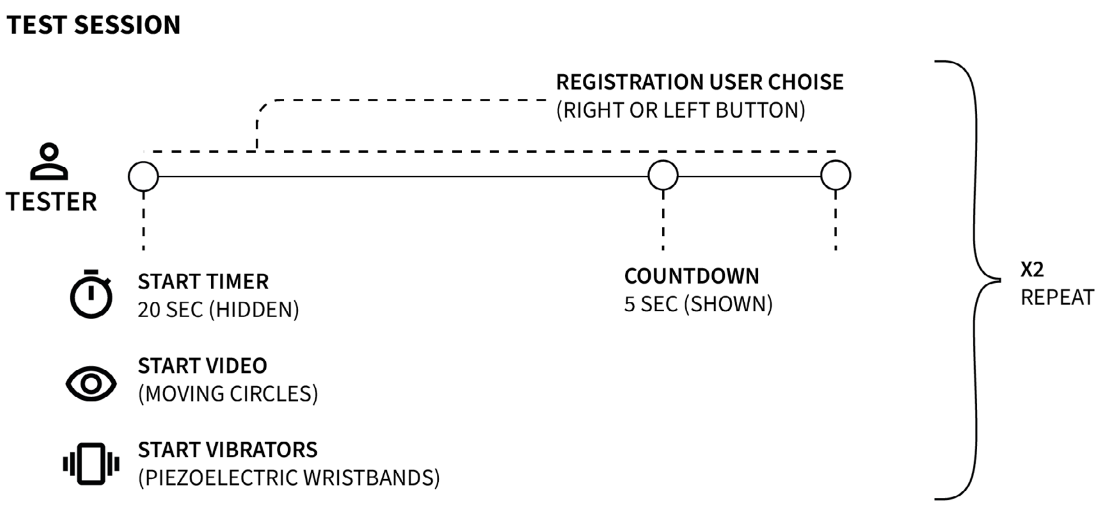

Figure 2. Experiment outline.

Figure 3. Layout of the experiment.

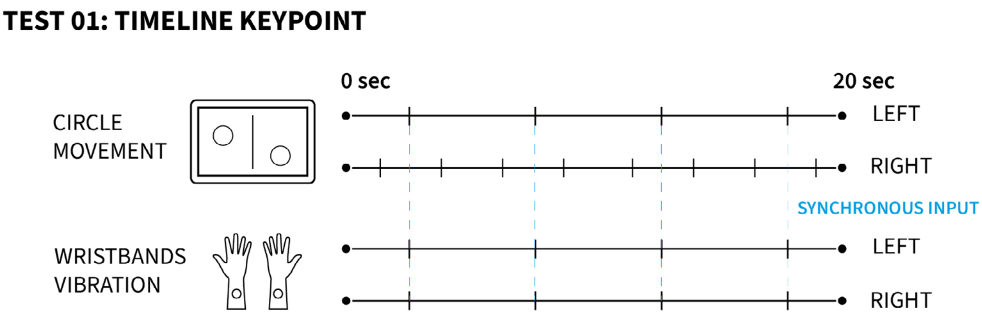

Figure 4. Test 01 process diagram.

The second test (Fig.5) introduces an element of interference in a manner similar to the experiments in the attentional domain that revealed the Simon effect (Simon, 1969). Specifically, the psychologist highlights a conflict between a spatially situated stimulus and a response required of the subject. If the subject is shown an object on the right side of the screen and asked to press a button on the left side, the response will have a slower reaction time than a location coherent with the question asked.

Coherently with the Simon effect in the second test, an asymmetry was introduced in the vibratory feedback on the wrists. The tactile feedback on the right wrist has a longer duration than on the left wrist. This results in a markedly stronger perception of the vibratory stimulus on the right body part. However, the rhythm of both wrists was equal and in synchrony with the circle on the left. The subject was then again asked to choose one of the circles before the 20-second time limit was exhausted.

Thus, two questions were tested with this test: the greater efficacy of choosing a synchronous stimulus over a persistent vibratory stimulus on one side of the body, the possible increase in response time compared with the test without an asymmetrical disturbance element. The second test was also repeated a second time by specularly reversing both the video and vibratory stimuli.

At the end of the exercises, each tester was asked to freely leave a written note about the sensations they felt during the test and the parameters on which they based their choice. Only at the end of this phase were some indications given about the objectives of the test and the research.

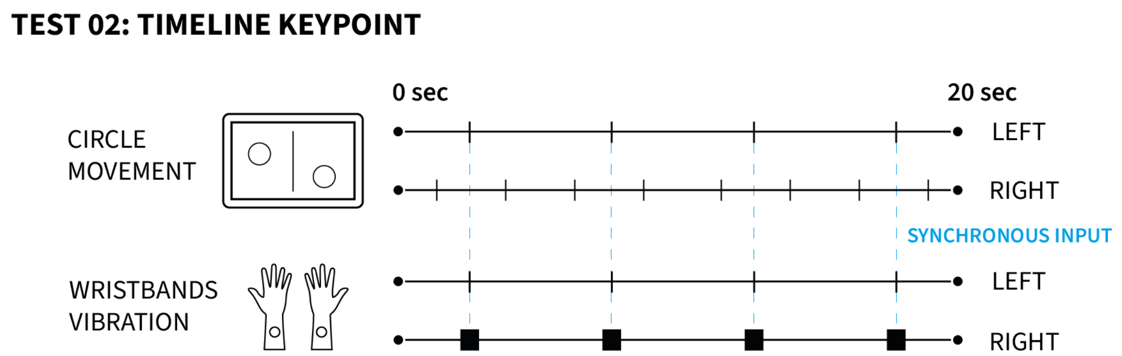

Figure 5. Test 02 process diagram.

5. Data Comparison

In relation to the group of subjects analyzed, the test results do not clearly show dominance in the choice attitudes of the subjects involved. Subjects who gave coherent choices with the cross-modal synchronic rhythmic stimulus investigated were 65.8 percent of the testers versus 34.2 percent. The positive percentage, while greater than the contrary choices, does not indicate a cross-sectional understanding of synchrony. However, it underscores the decoding of the phenomenon of synchrony for a good portion of the subjects.

The table below (Tab. 1) shows the results of the tests conducted. The data analyzed covers 19 subjects; tester No. 16 was cancelled because he reported in the commentary an abnormal functioning of the prototype.

In the Synchronic Choice column, the table reports when the tester's response was coherent with rhythmic synchrony (Y) or when it was different (N). The reaction time for the choice is reported for each question. When the choice was made after the end of the test, the maximum time of 20 seconds of the test was allotted.

5.1 Synchronic Choice

In test No.1A, the majority of testers (14) chose the ball that moved in sync with the rhythm of vibration. This number was significantly reduced in test No.1B where the percentage of testers who gave a positive choice (9) was smaller than those with a negative choice (10).

In test No.2A, the percentage of coherent choices with cross-modal synchronous perception became prevalent again with 14 coherent choices out of 5 inconsistent ones. The result is aligned with test No.2B with 13 positive choices out of 6.

Looking at the choices given by each tester, we can see that only 4 of them gave 100% positive choices, 6 gave 75%, 6 gave 50%, and 2 gave 25%. One subject gave all negative choices.

5.2 Reaction Time

Most of the subjects made their choice before the 20 seconds expired. Out of a total of 75 responses, 21 were given before the middle of the test (10 s) while 46 were given before three quarters of the test (15 s).

Observing the data in a comparative manner of test No. 1A and test No. 1B shows a general increase in reaction time. However, looking only at the data for coherent choices with synchrony, the average reaction time drops from 14.037 s to 12.685 s.

The comparison of reaction times between test No.2A and test No.2B is different. The overall average reaction time rose by almost 4 seconds as that for coherent answers with synchrony rising from 9.857 seconds in test No.2A to 14.467 seconds in test No.2B.

Analyzing the overall averages of the cross-modal coherent answers increased from 13.361 seconds in the first two to 12.162 seconds in the third and fourth exercises.

Table 1. Results of tests. Yes (Y) means a choice potentially based on synchrony, No (N) means the opposite. The Reaction time column indicates the time it takes for the tester to press the choice button (from the start of the test).

Test n.1A		Test n.1B		Test n.2A		Test n.2B	
Synchronic Choice	Reaction Time (s)	Synchronic Choice	Reaction Time (s)	Synchronic Choice	Reaction Time (s)	Synchronic Choice	Reaction Time (s)
Y	15,075	Y	15,879	Y	6,442	-	-
N	3,394	N	10,659	N	7,765	N	12,095
Y	14,332	N	12,661	N	13,499	Y	12,862
Y	20,000	N	17,593	Y	6,527	N	3,865
Y	20,000	N	12,995	Y	11,404	N	20,000
Y	9,728	Y	8,261	Y	5,426	Y	20,000
N	15,762	Y	12,330	Y	16,333	Y	17,294
Y	16,097	Y	17,663	N	18,031	N	20,000
Y	18,700	N	18,899	Y	15,564	Y	11,794
Y	3,937	N	16,737	Y	17,604	Y	17,171
Y	4,204	N	11,638	N	12,404	Y	12,300
N	10,070	N	12,169	Y	6,342	Y	17,937
N	7,469	N	8,405	Y	4,238	Y	7,671
Y	18,371	N	20,000	N	17,536	N	19,904
Y	11,471	Y	13,599	Y	9,971	Y	11,769
N	10,804	Y	7,870	N	5,869	Y	13,838
N	3,471	Y	10,802	Y	6,204	Y	7,871
Y	10,969	Y	11,002	Y	8,271	N	11,538
Y	13,635	Y	15,433	Y	12,771	Y	16,936
Y	20,000	Y	9,199	Y	10,899	Y	20,000

6. Discussion

The introduction of test repetition is directed to verify an increase in coherent choices following the experience in the first test. In contrast to the initial assumption, test repetition shows a decay in coherent choices with the perception of a cross-modal synchronous rhythm. These results could indicate how synchrony is quickly encoded by subjects; however, over a longer time, other factors take over in guiding the final choice.

This observation holds true for both tests conducted. While in the former we see the actual decay of coherent choices, in the latter what visibly changes are the increased reaction time of the decision. This could be due to uncertainties the testers had.

Test No. 2 was designed to challenge the perception of synchrony. To do this, an interference factor was introduced. However, the results do not show a deterioration in coherence compared with test No. 1. On the contrary, the increase in vibratory sensation, although asymmetrically with respect to the body, led testers to choose a coherent choice with synchrony. This was also the case in the repetition of test No. 2. The diagram below (Fig. 6) compares the percentage for each tester of coherent choices in rhythm with the observations they wrote on a sheet of paper at the end of the two tests. The observations were read, and each was assigned the prevailing perception described by the tester (1 subject declared nothing, 2 subjects declared confusion, some testers placed greater importance on the sense of sight, and a greater number reported placing great importance on vibration). Finally, many testers indicated that they felt a shared rhythm or synchrony between the visual and tactile sensations even though this did not always then match the choices.

The graph is interesting because it highlights how testers were aware of the phenomenon of synchrony and tried to guide their choices based on this. In the testers' declarations, touch had a greater incidence than the sense of sight.

The data analyzed support further development of cross-media synchrony and application in multiple application areas. One example is the attention relationship between visitors and information content in museum and exhibit. Another area is safety in the workplace through increased awareness of body-contact information. Finally, the rehabilitation field could also accommodate further development of the topic.

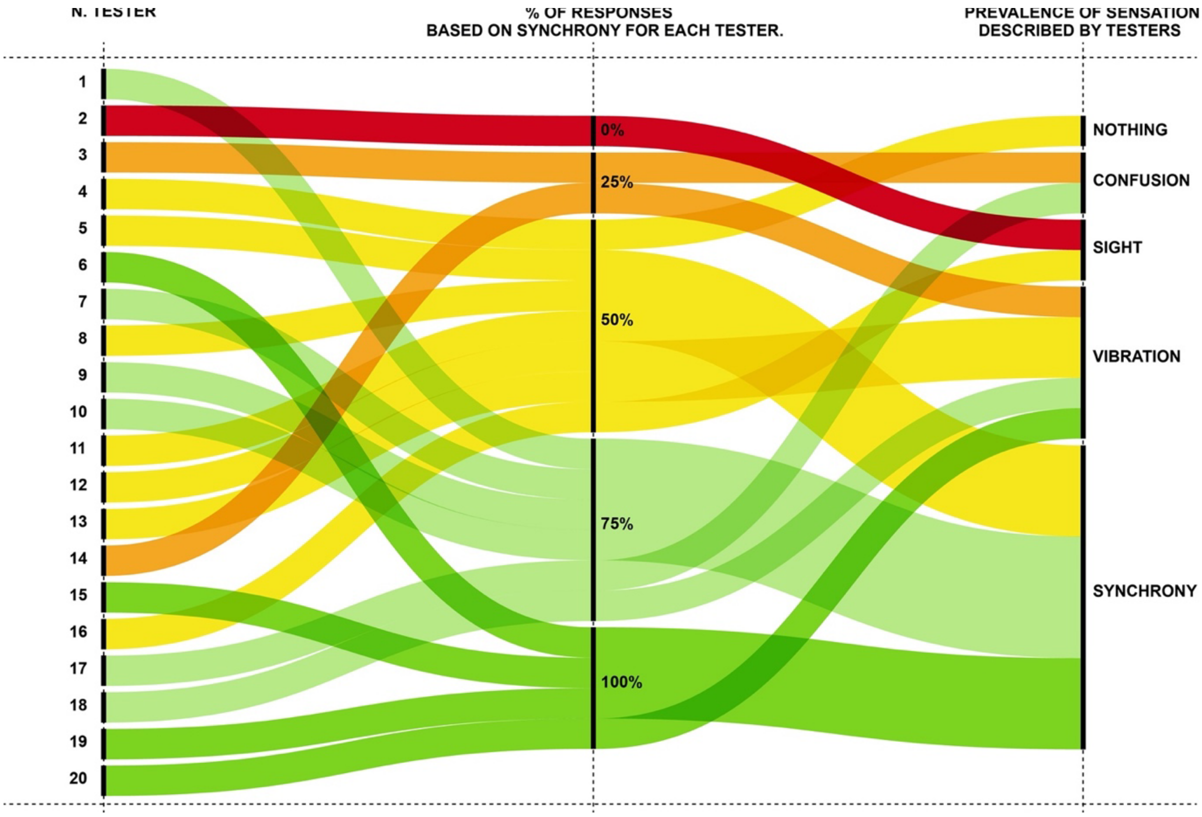

Figure 6. Alluvial diagram of research results. The diagram highlights the relationship between the percentage of responses consistent with the synchronic stimuli and the sensation communicated by the subjects after the two tests.

7. Conclusion

Public and private spaces are increasingly integrated with pervasive digital technologies and invisible human-machine interfaces. Therefore, in the field of interaction design, it is necessary to introduce design elements that support attentional processes capable of integrating naturally with human senses.
The characteristics of touch, such as noninvasiveness and proximity, grant haptic technologies a high degree of mimicry and personalization of information while respecting the user's privacy. This makes them useful for handling various types of messages between the body and the interactive systems around it.
One can imagine a personal scenario in which notifications arrive silently to only one user compared to other people in the same room. For example, the alarm clock in the morning vibrating on a wearable could wake only one person from a couple living together, or messages received within a crowded study room.
These scenarios are already widespread in the haptic device landscape but anticipate broader design scenarios yet to be studied in the field.

Among the many components that come into play in the modulation of haptic technologies used in human-machine languages, rhythm is a determining factor in consciously and unconsciously suggesting responses in people's behavior. Synchrony is a rhythmic phenomenon that the body perceives with its senses, and there is evidence that the human body can associate multimodal sensations, that is, from different sensory channels. Rhythm has cross-sensory communicative capabilities (cross-mediality) and can relate multiple senses simultaneously (cross-modality).

The possibility of advanced integration of designs that work on haptic stimuli in the field of immersive and at the time expository technologies becomes central to the design of experiences regardless of whether they are physical or virtual. The complexity dictated by the addition of media that is conveyed through haptic vibration requires a long phase of design experimentation. The evaluation proposed in this contribution demonstrates that this direction is viable at both the conceptualization and developmental levels.

7.1 Limitations and Future Developments

The experimental tests conducted show that cross-modal rhythmic and synchronic stimulation has a good ability to guide users' choices. However, some boundary factors emerge within this study that need further analysis to check for possible interferences in the evaluation of the results. For example, additional factors come into play in determining a choice preference that may lead subjects to act differently.

Following the experiments, some evaluations emerged in the data analysis regarding the subjects' prior experience with respect to rhythmic perception. Previous musical experiences by the testers may have contributed in rhythm perception. Lack of familiarity in the use of smartwatches by some testers and lack of familiarity with vibration sensations in the wrists may also have influenced the responses. A larger sample that takes these factors into account could be the subject of a subsequent exploratory investigation in which these first two experimental tests could be supplemented by additional items for evaluation.
To improve the quality of stimuli sent to the body, wireless haptic bracelets will be used in future experiments. The use of wearables will allow testers to assume a more comfortable and less constrained position. In addition, the wearables will also allow some tests to be conducted with the body moving within a controlled space.

The experimentation lays the groundwork for further research around cross-modal synchrony as an element in engaging people and supporting decision-making and attention processes in digital information-dense environments. Subjects' response to synchrony effects underscores the opportunity for applications designed to increase the connection between the body and the interface in immersive experiences.

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