NAVIGONS — Analyzing tactons for navigation

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ABSTRACT

Vibro-tactile navigation systems use the sense of touch across numerous application contexts and motivations. The vibro-tactile patterns (tactons) deployed to transmit the information are often tailored to the scenario and the respective hardware. Without an appropriate classification system, it is difficult to compare tactons with each other or to identify their potential for new use cases. Therefore, we apply the previously developed taxonomy VibTacX to a set of tactons used for navigation tasks – NAVIGONS. Following, we present and discuss the identified characteristics of the use cases. Furthermore, the application of VibTacX acts as a filter system to identify and investigate similarities and differences independent of the use cases. This procedure may be the basis for the structured development of tactons. Hence, we conclude with an outlook on future design guidelines for vibro-tactile user interfaces and the qualitative improvement of tactons.

CCS CONCEPTS

• **Human-centered computing → Interaction design process and methods**; *Systems and tools for interaction design.*

KEYWORDS

vibro-tactile, tacton, navigation, taxonomy, human-computer-interface, interaction design

1 INTRODUCTION AND MOTIVATION

In the field of human-computer interaction, navigation is considered as one of the basic interaction tasks alongside the selection and manipulation of objects [3]. This can be further differentiated into two modes of operation. If an object or location is to be found or retrieved, it requires efficient and therefore restrictive route planning. In contrast, freedom of exploration is required, if the focus is on discovering a foreign environment [4]. Especially for the process of route planning, there are numerous solutions available. People traditionally use maps, signposts, or compasses for navigation tasks. Modern technology introduced digital assistance systems especially into vehicles. Here information is given as voice commands or shown in the driver's field of vision via special displays (e.g. head-up display). For pedestrians and cyclists, map services are available online using smartphones. These must compete for the attention of their users with surrounding environmental cues.

An alternative to the use of the audio-visual senses is the sense of touch, which is targeted by vibro-tactile systems. With the help of vibro-tactile displays, information is converted into vibrations and transferred to the user's skin. Vibro-tactile patterns, also called tactons, "[...] are structured, abstract messages that can be used to communicate messages non-visually" [2].

Vibro-tactile navigation systems aim to provide immediate, low-distraction and often invisible guidance. These systems are suitable for both restrictive and exploratory guidance. The tactons and vibro-tactile displays developed for this purpose represent individual solutions that have so far neither been compared nor classified in terms of an ordering system (taxonomy). However, this is necessary, to gain insights from current implementations and to be able to develop new tactons sufficiently.

Initially, this paper provides an overview of previous work on tacton-based navigation. Furthermore, these should be differentiated according to *intention*, *design*, and *presentation*. From this, initial criteria for the design of vibro-tactile interfaces and tactons in the field of navigation (or NAVIGONS) can be derived and transferred to new applications.

The main contribution of this paper is the application of an overarching taxonomy to a fixed set of tactons and the stepwise evaluation of the classification. First, we present the types of navigation and collected tactons as a data basis and roughly sort them with regard to their intention. In the method section, the taxonomy VibTacX [22] is explained and then applied in the following to analyze the tactons. Gained insights are presented and discussed in the results section. The paper concludes with a summary of the results and an outlook on further developments.

2 TYPES OF NAVIGATION

Darken and Silbert [4] differentiated the intention of navigation between *exploration* and *search*. The associated characteristics are briefly explained in Table 1.

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Table 1: Comparison of navigation types exploration and search in terms of use and provided information

Criterion	*Exploration*	*Search*
transmitted information	direction and (linear) distance to destination or next waypoint	next waypoint and instruction distance (route) to waypoint distance (route) to destination
direction of navigation	destination or next waypoint	next waypoint
instruction	no	yes (sometimes with confirmation)
output	continuously or by request	before instruction (feedforward) at time of instruction after instruction (feedback)
efficiency-oriented	no	yes
distance to destination	linear distance	route

The intention of *exploration* is to get familiar with an unknown place. Starting at the user's location, the environment is gradually discovered and mentally marked. The system utilized for exploration is intended to offer safety to the user while moving freely in an unknown environment by displaying the direction to a fixed landmark in a compass-like style. The distance, however, is coded more abstractly (e.g. in gradation/nuances of intensity). Due to the stated intention, such systems are not restrictive. Outputs can be initiated by the user or played out continuously.

The purpose of *search* is to guide the user to a desired destination as efficiently as possible. Therefore, technical systems use a restrictive routing with few but clearly discernible instructions. Depending on the designer's choice, the distance to the destination or next waypoint is displayed as an advance notice (feedforward). The actual instruction encodes both the direction and the prompt to turn. Successful compliance with the instruction (e.g. "turn left") can be shown separately to the user with additional feedback.

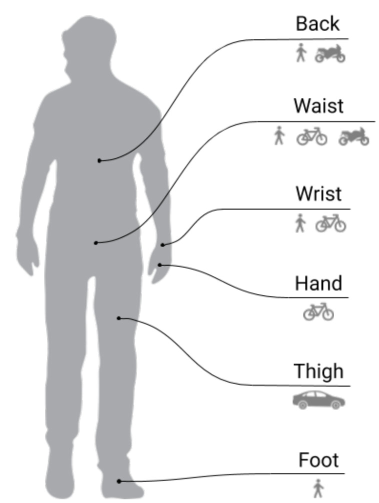

Figure 1: Overview of locations where vibro-tactile displays are attached to the human body (Back [5, 14], Waist [7, 8, 16–18, 20], Wrist [1, 6, 9], Hand [10, 13], Thigh [19], Foot [15]) and their context of navigation.

3 DATA BASIS

In this study, 16 publications with a total of 58 tactons were examined. Six publications described implementations of free systems for exploration [7, 12, 13, 15, 17, 20], nine described restrictive ones for efficient guidance [1, 5, 6, 8–10, 14, 16, 19], and one paper was without clear classification [18]. The application context was mainly related to navigation on foot (7) or by bicycle (4). Other use cases were cars (1) and motorcycles (2). Two studies could not be assigned to a clear application. The contact surfaces of the vibro-tactile displays were preferably the user's waist and hands (especially wrists). Further areas were the legs and feet respectively. A description of the locations and contexts used, is shown in Figure 1.

4 METHOD

In order to get an overview of tactons for navigation tasks, it is necessary to analyze and compare them with each other based on certain criteria. The taxonomy VibTacX [22] is used as a tool for this investigation. It combines several aspects that can be taken into account both in application-oriented comparisons and in the creation of new tactons. An overview of the criteria hierarchy of VibTacX is shown in Figure 3.

Following, the components of the taxonomy relevant for the analysis are briefly introduced. For a more detailed consideration of the taxonomy, please refer to the paper by Wittchen et al. [22].

VibTacX consists of three categories: *intention*, *design*, and *presentation*. The tacton is analyzed in the predefined order, as the intention influences the design and ultimately the presentation. The category *intention* includes three kinds: *output*, *response*, and *instruction*.

Output includes all tactons that transmit information or conditions to the user without prompting him to take action. An example would be the position of the destination or its distance to the user.

Tactons that are classified with the intention of *response* describe a one-time event that is triggered by the system. In the field of navigation, this would be the information that the user has reached his destination. In addition, interrupts can also be interpreted as a

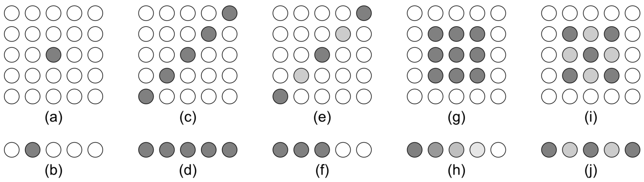

Figure 2: Examples of geometric shapes ([a] and [b] point; [c]–[f], [h] and [j] line; [g] and [i] plane) in tactons on different display shapes (top row: plane-display, bottom row: line-display). The shade indicates the intensity of each actuator — the darker, the stronger (white means off).

response, suspending the normal process to inform the user that the battery of the navigation device is empty, for example.

The third type of intention, named *instruction*, includes calls to action. Ideally, these tactons form a common vocabulary of output- and response-tactons to announce recommendations for action (output) and to confirm their successful execution (response).

The second category of the taxonomy is the *design* of a tacton. As shown in Figure 2 each tacton can be interpreted as a set of geometric primitives (e.g. point, line, or plane) that can change over time (e.g. a point pulses in intensity). Therefore, using basic forms and their transformation plays a central role in the classification of tactons.

The third category is the *presentation* of a tacton on physical output devices – vibro-tactile displays (see Figure 2) – and the type of playback (e.g. repetition). With regard to the output device, it is significantly relevant to know how many motors are placed on such displays and where they are located on the human body.

For the analysis, papers were selected from the navigation area with respect to various aspects. Papers with restrictive and free approaches should be considered as well as different technical structures and applications. Included tactons were elaborated and applied to the sequence of *intention* (1), *design* (2), and *presentation* (3) described in the taxonomy (see Figure3).

5 RESULTS

After classifying tactons into VibTacX, they were compared with each other, concerning the main characteristics contained therein. Due to the scope of the investigations, the observations made only indicate tendencies. They are presented below and discussed in the next section.

(1) Under the criterion of *intention*, it became clear that there is a noticeable difference between tactons for free and restrictive systems. Tactons used in free systems (*exploration*) mainly represent outputs. These encode the direction to the destination or a waypoint and often its distance to the user. In contrast to this, the primary intention of tactons within restrictive systems (*search*) is guidance. However, they also often occur in connection with outputs. Contents of these tactons are mainly clear instructions, such as "turn left". Often there are advance notices for these calls for action in the form of outputs, in which distance is coded as well. The output can also be interpreted as information, e.g. "wrong direction". In restrictive systems, response tactons could be recognized as confirmation (e.g. a successful turn).

(2) The *design* of tactons is strongly linked to the selected hardware configuration. Accordingly, simple geometric forms dominate the shape of the tactons - mainly points. This simplicity is also reflected in the intention to be realized. *Output* and in particular *response* is implemented as simply and concisely as possible (e.g. a short buzz). In the case of outputs, quantitative features, such as distance to the next turn, are added by changing the intensity of the actuators. Transformations, however, are only used for prototypes with linear or surface vibro-tactile displays. This is certainly limited to the intention of an instruction, whereby mostly harmonic movements are represented to illustrate the direction to turn.

(3) For the *representation* of tactons, all forms of vibro-tactile displays included in the taxonomy are used. As with the design, more prototypes rely on simple geometric shapes - mainly point-displays. These are often attached to the arms (especially wrists). In order to keep the tacton structure simple, several vibro-tactile displays are located at different parts of the body. In contrast, more complex display forms, such as line- or area-displays, are preferably located on the torso and occur less frequently in a combination of several displays. The playback of tactons in one-time and repeated form could be observed on all display forms as well as in all applications at approximately the same rate. The comparison of free and restrictive systems shows a slight preference for repetition prevails in free systems, whereas no statement can be made about a preference in the case of restrictive systems.

6 DISCUSSION

At this point it should be mentioned that the scope and diversity of the considered data set is limited. Consequently, no quantitatively reliable statements can be made from this, but trends might be identified. In general, there is a need to further investigate the type and use of tactons.

(1) The results of the intent-analysis support the statements outlined by Darken and Silbert [4], which describe clear differences between free and restrictive systems. Regarding our observations of restrictive systems we assume, advance notices (feedforward) should prepare the user for the following action. This may also reduce ambiguity in the event of several upcoming turning options. In contrast, we could not identify corresponding (feedforward-)tactons for exploratory systems in our data basis. *Response*, still rarely used in the present data set, should also be part of it, to provide the user with safety. These aspects not only contribute to good usability but also to ensure the most efficient navigation. For the design of tactons in free systems, one thing in particular can be deduced: it is important to restrict the user in his actions as little as possible and avoid any disturbance by obtrusive navigation. It is therefore advisable to use outputs rather than *instructions*.

(2) The simplicity of tactons used in navigation indicates that their design was influenced both by the minimal technical setups as well as the desired maximum contrast between individual tactons. The latter ensures minimal cognitive effort for the interpretation of the tactons when performing a navigation task. In this context, the creative use of transformations, among other things, may contribute to a better perception of the intention of a tacton. We assume that the creative leeway will receive a new impetus with the help of

higher resolution vibro-tactile displays, equivalent to the development of modern monitors. There is a considerable need for research in this area.

(3) Restrictive systems often use several point displays at different parts of the body to display tactons, e.g. to show the direction left on the left hand. In contrast, line-displays use a higher number of actuators on one body part (e.g. torso) to clearly indicate directions. Thus, both the localization and the higher resolution seem to be key features to improve the recognition of tactons. The design of vibro-tactile displays is also influenced by human habits. Wearing belts or bracelets is common and socially accepted. In addition, both areas are easy to reach and, unlike the head or feet, they offer the possibility to easily attach those displays. Accordingly, these technical solutions can often be found in different contexts.

As demonstrated in this paper, VibTacX only classifies single tactons, whereas some use cases compose multiple tactons to achieve certain interactions. Therefore it is necessary to consider the entire context, which may lead to an advanced version of our taxonomy or another classification system.

7 SUMMARY

In this paper, the use case 'navigation with the help of tactons' was investigated. We created a collection of representative papers and examined in terms of the central navigation intention (*exploration* or *search*) and the tactons used. This was arranged using the taxonomy VibTacX with regard to the main criteria *intention*, *design*, and *presentation*. The findings derived from this were presented and discussed.

An essential point is that a fixed set of necessary information has been established in the use case of navigation. Accordingly, their *design* and *presentation* has remained constant over the last years. However, new applications (e.g. cycling) could be developed and innovative forms of locating vibro-tactile displays on the body could be tested. Investigating restrictive systems, it becomes clear that their aim is guiding users to take action by means of clear and easily distinguishable tactons. A necessary preparation in the form of advance notices (feedforward) as well as a corresponding response (feedback) is not yet fully established and occurs seldomly in the investigated amount of work. The freedom of the explorative approach consists in interpreting the represented tactons or ignoring them entirely. It is thus completely up to the user to decide whether and how he wants to react to them.

The tactons and technical systems used for navigation are currently minimalist, but well adapted to each other. However, this entails that the currently used vibro-tactile displays are a restriction for further development of the use case and the design of tactons. A motivation for the progress of the vibro-tactile hardware is currently not based on the case of application and is therefore not primarily driven forward. It is more likely, however, that further development will take place in other areas where the quality of the vibro-tactile displays is a decisive factor for the successful use of vibro-tactile systems [11, 21].

Perspectively, navigation can benefit from this, by incorporating the quality of the geometric shapes used in the tactons and their changes over time into a holistic design process. This means that in the future even complex activities will be supported or guided in a vibro-tactile way. Therefore it will be required to create corresponding sets of tactons. Necessary guidelines for design and for ensuring usability are only just emerging. The historical progress of the graphical user interface can serve as a model for this purpose.

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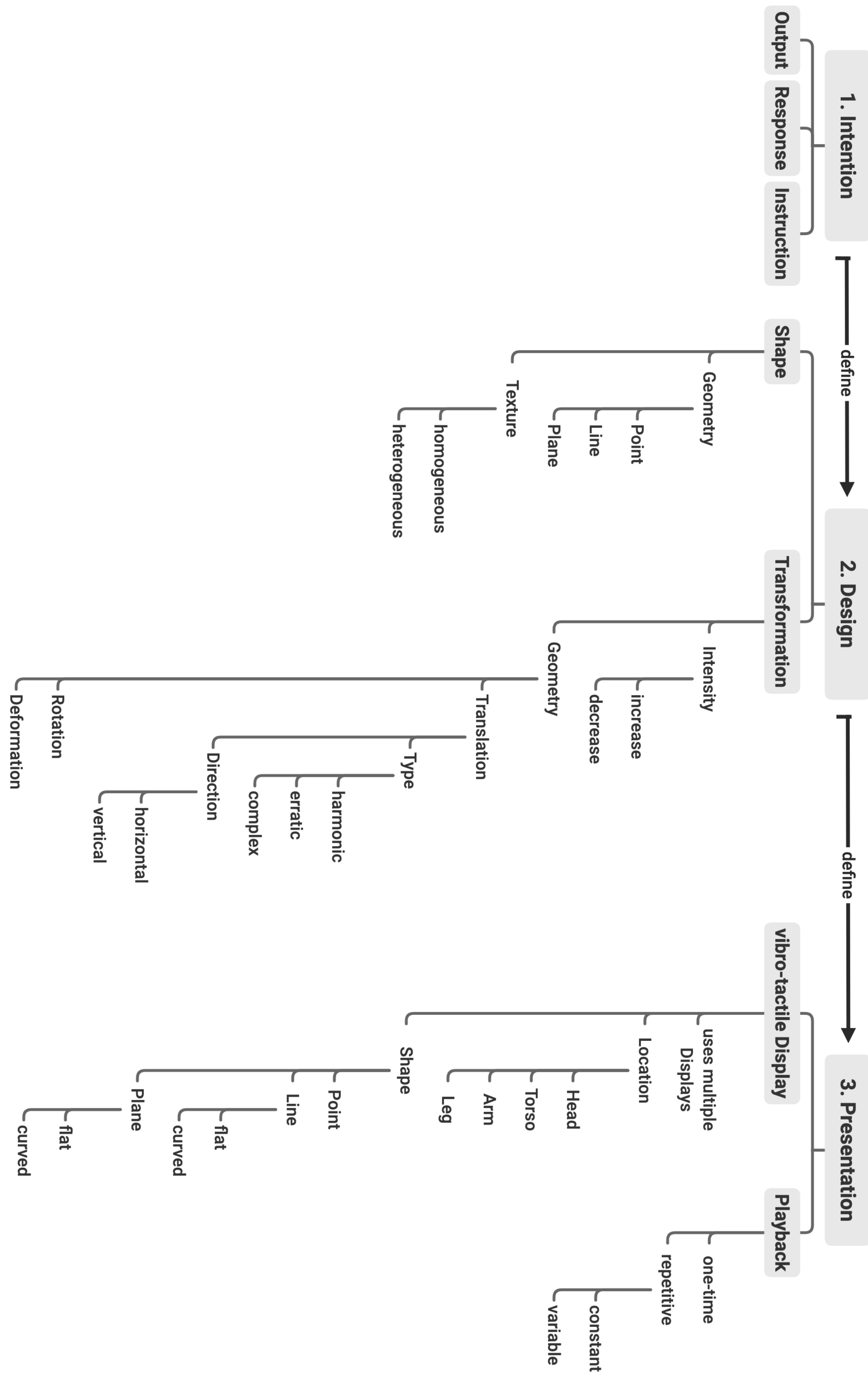

Figure 3: VibTacX is a taxonomy for vibro-tactile patterns (tactons) developed by Wittchen et al. [22].