Closing the Loop of Sound Evaluation and Design (CLOSED)

Deliverable 4.2
Selection of relevant sounds and standardisation proposal for functional measurement.

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1 Introduction

During the first part of the CLOSED project (Deliverables 4.1 part I and II), we have studied the perception of everyday sounds. Specifically, we have investigated the relation between the classification of everyday sounds and the type of similarity used during categorization. This type of similarity can be explained by how well the event causing the sound is identified, and by the expertise of the listeners. This study has allowed us to propose a classification of everyday sounds based on sound event categories.

The different categories of sound events are a central idea for the CLOSED project because sound causality can be used to create new sonic designs based on the study of basic interactions during everyday settings, for example in the case of the kitchen scenario (see Deliverables 3.1). The SDT toolbox – based on the cartoonification of sound events – provides a way to create continuous sonic feedback for the prototypes of the interactive sonic artifacts developed by ZHdK (see Deliverable 2.2). These prototypes afford simple manual interactions, and are useful for testing different hypotheses: relation between the use of interaction gestalts (Deliverable 3.2) and the dynamic of the interaction – and functional-aesthetic assessment during a task.

The goal of this deliverable is three-fold. It aims first at selecting sounds for the prototypes developed by ZHdK, using the SDT toolbox developed by UNIVERONA. It also aims at developing methodologies for the measurement of functional-aesthetic assessment. Finally it aims at studying how manipulating a device that makes sounds lead to a different perception of the sounds. Indeed, studying interactive prototypes that make sounds (participants make the sounds) involves new methodological challenges, compared to the study of the passive perception of sounds (participants listen to sounds). The goal of this deliverable is therefore to adapt the psychophysical methods to sonic interactions.

The experiments reported in this Deliverable have focused on a specific prototype: the Spinotron (see Deliverable 3.1 and Deliverable 3.2). This deliverable is split in two parts, corresponding to two distinct sound models embedded in the Spinotron. The first part uses the model of a ball rolling in a tilted bowl. The second part uses the model of a ratcheted flywheel.

In the first part, we use a model of a ball in a bowl developed by ZHdK. In this model, a ball is rolling in a tilted bowl, the bowl being tilted when the user pumps the Spinotron. A psychophysical experiment is conducted to assess if (and how well) listeners are able to judge the height of the ball rolling in the bowl, only by listening to the sound of the ball rolling. The goal of this experiment is to tune the sounds in a such way that the listeners can pump the Spinotron to maintain virtually the ball at a certain height within the bowl.

However pilot studies showed that the dynamic of this system is too difficult to control the height for a performance task. Therefore, we use in the second part a second model developed by ZHdK. It is a model of a rotating ratcheted flywheel including a more direct mapping between the speed of the pumping and the speed of ratchet rotation. This model has 3 different dynamical modes. The first mode corresponds to the physical model of the actual dynamics of the ratchet. Two other modes are also used, corresponding to deviations from the physical dynamics. The idea is to progressively break the coupling between gesture and sound, from a coherent dynamics to an arbitrary coupling between gesture and sound.

There are 3 experiments reported in this second part. First, in a psychophysical experiment, we estimate if listeners can judge the speed of ratchet only by listening to the sounds.

The goal of the second experiment is to select presets of the ratchet model that provides the best understanding of the ratchet mechanism. Moreover, we also test in this second experiment different configurations (static and evolving sounds) to investigate if the dynamics of the sound can influence the perception of this sound event, i.e. the representation of the cause of the sound.
The last experiment deals with the measurement of the functional-aesthetic aspects of the Spinotron. In this experiment, the participants have to perform a task: they have to pump the Spinotron so as to maintain the speed of the ratchet constant. It is a learning experiment: participants have to learn across trials and tests the correct way of manipulating the Spinotron to get a constant speed of the ratchet. In this experiment, we first test how manipulating the device that makes the sounds changes how the listeners perceive the cause of the sounds. We also test whether the sounds actually guide the participants in maintaining a constant pumping pace. By studying the speed of the learning throughout the three dynamical modes (3 groups of participants), we aim at comparing how varying the coherence of the coupling between gesture and sound might affect the easiness in learning the behaviour of the device. The hypothesis here is that a gesture/sound coupling modeling a physical interaction will be learned more easily than an arbitrary coupling, because participants have already experienced this kind of coupling in their everyday life. Finally we also study how the participants assess the functional-aesthetic aspects of the device before and after having performed the task, by asking them to report judgements of functionality and preference.

Through these different experiments, we aim at developing a methodology to investigate the functional-aesthetic aspects of an interactive sonic device: we combine traditional evaluations with scales and methods based on measuring how participants perform with the prototype.
2 Related work

2.1 Sound in HCI: From Iconic to Dynamic

The HCI domain has evolved a lot these last 30 years. Many methods for interaction have been developed, making use of a great variety of devices and a great variety of techniques, and sound is no exception.

Mobile phones or mp3 players are a great area for experimenting with new sonic interfaces. For example SonicTexting [19] enables writing an SMS using only touch and sound with the hand in pocket. The Shoogle prototype [31], for mobile device is based on active perception, for example shaking the device give information about the state of the battery or about the contents of the SMS inbox, the sonic feedback is made of simulated balls. The earPod [32] for mp3 player, uses a radial sonic menu to navigate within content based on vocal and feedback sounds.

One important issue, as previous examples shown, is then to decide how to communicate the information. Different problems arise on the type of sound and the type of interaction. A lot of effort done using sounds in HCI had usually dealt with sounds in the form of short static signals, typically warning or feedback sounds. The use of these sounds are now relatively common in applications like hospital or car equipment, or high performance aircraft [14, 3, 24]. In a different approach, several virtual systems using iconic (or metaphoric) sound notification to provide efficient awareness of the different steps of a process were proposed by Gaver [5, 6, 7] (see, for example, the Sonic Finder, ARKola and EAR [7]). Gaver’s hypothesis on iconic sound representation was that there are similarities between informations provided by everyday sounds and concepts in virtual environments, and thus informations on virtual objects can be augmented with an acoustical behaviour similar to those of related counterparts in physical environments.

More recently, Gaver’s idea was extended to dynamical sonic interactive devices [13] using real time sound modelling of a mechanical phenomenon causing the sounds [12, 20]. The use of such a causal representation, instead of an abstract one, is based on the hypothesis that sonic interactions with virtual objects should be perceived as naturally as possible without spending too much cognitive effort to understand and to decode the message of the sound feedback.

For example, in [12], the interactions between a pen and a board is sonified by synthesizing different qualities of the surface and of the pen (chalk on slate, boardmarker on a flipchart, etc.) and the type of gesture produced when handling the pen on the surface (pen-down, pen-up, etc.).

A workshop on Sonic Interaction [22] has recently been a important contribution to the field. Particularly, several aspects for the emergence of the sonic interaction design have been highlighted:

- A need for real time sound model for simulating everyday sound interactions [1].
- A connection with the field of sonification for displaying useful information [8].
- A transition from discrete to continuous real time and multisensory interaction [21].

These latter remarks emphasize the importance of the multisensory aspects of sonic interactions. Particularly relevant to sonic interaction is therefore the action and perception coupling.

2.2 Action and perception

The study of human-computer interaction entails an understanding of the perceptual-motor behavior because of the different processes that underline an interaction. Different methodologies have been developed, generally in the framework of information-processing theory, to study human-computer interaction [15]. For examples, reaction times, movement times or other chronometric measurements
have been widely used. Classical assessments of input devices has shown important results of the advantage of the mouse [30] and given the famous Fitt’s law [4] that predicts the time to reach a target as a function of the distance to the target, and of the width of this target. This studies have focused on time to produce a movement, but have not necesseraily taken into account other factors that can influence the time required to perform a movement (for investigations of this latter issue, see [30]). But in the case of a design involving continuous sonic feedback for the user, a dynamic loop between perception and action is engaged. Such dynamical perceptual-motor interactions “may not be best indexed merely by chronometric methods” p. 29 [30] and new methodologies has to be found.

Enaction is another theoritical approach to perception and action. The concept of enaction is developped in the work of [28]. Following [2], enaction is considered as the third type of knowledge (representation of experience): iconic representation (image-based or other sensory organization), symbolic representation (language-based), and enactive representation (action-based). Enactive knowledge is therefore natural and based on intuitive and perceptual experiences [29]. Enactive knowledge emerges from action, and is grounded on physical and informational regularities of environment [29]. However, if the enactive approach to sound perception provides a very interesting theoretical framework to conceptulize the interaction between perception and action, only few experimental methodologies are currently easily transposable to study sonic interaction designs.

The methodology developed in [16, 17, 18] provides an interesting example of how sonic interactions might be experimentally investigated. The Ballancer is a tangible interface consisting of a wooden plank that may be tilted by its user, in order to drive a virtual ball rolling along the plank. A user tilting the latter hears the rolling sound produced by the virtual ball. This rolling sound is produced by a synthesis model that allows to vary the size, mass and shape of the ball. The authors used this interface to study subjects’ abilities to use the auditory feedback in a task involving guiding the ball to a target region along the length of the plank. They found that the auditory feedback, in combination with a visual display, allowed users to guide the ball to the target area more rapidly compared to a case in which they were provided with visual feedback alone. Moreover, in a comparison using the same task with the rolling ball sound and with a “synthetic” sound (i.e. one that does not mimic any physical system) that preserves the same information, subjects were found to perform better, early in training, with the realistic sound than with the “synthetic” one, whereas the latter provided better performance after training. Participants reported having preferred the realistic sounds, despite performing better with the “synthetic” feedback.

The methodologies used at IRCAM for studying sound design is related to experimental methods ground in psychophysi and cognition in the field of information-processing framework. Our work is generally based on psychological experiments involving participant listen to sounds and responding in different ways to instructions (scales, classification task, description, alternative forced-choice, ...). These different experimental protocols involved generally a specific listening: participants listen to sound, in a context of use or not, but sounds do not changed in a continuous way according to their action. This different studies are focused on the ”stimulus identification” and the ”the response” rather than the relationship between perception-action like in dynamic interaction.

Nevertheless, this approach is very suitable in order to define rules to create non interactive sound designs. Different studies about the design of car horns [10], sounds of interior cars [9], warning sounds [23] and perception of soundscapes in train stations in order to propose sound signaling [27], etc. have given specifications to design sounds for a specific use (alarms, auditory icons, sound signaling, etc.). In this paper we try to develop a methodology in order to evaluate functional-aesthetic aspects of sonic interaction desing based on psychophysical experiments to first study the perception of the sound event and after a methodology to study usability in dynamic situation in the framework of HCI.
3 Experiment with the ball in the bowl

3.1 XP2.2.0 Perception of the height of a ball rolling in a bowl

3.1.1 Method

Participants

Twenty participants (6 women and 14 men) volunteered as listeners and were paid for their participation. They were aged from 23 to 65 years old (median: 35 years old). All reported normal hearing. Nine of them reported high skill in music or sound analysis (professional musicians, musicologists, sound engineers, acousticians). The other 11 were considered as naive. The participants were all French native speakers or demonstrated high skills in French.

Stimuli

The sounds originated from the synthesis patches developed by ZHdK, based on UNIVERONA’s SDT. The synthesis was made to simulate the sound of a ball rolling in a bowl. Five presets of parameters were used, corresponding to different configurations of ball size and materials and bowl shape, roughness, and material. The parameter values for these presets are listed in Table 5.1. For each parameter preset, sounds were created, corresponding to 10 different heights of the ball (0.15, 0.30, 0.45, 0.6, 0.75, 0.9, 1.05, 1.20, 1.35, 1.50). The sounds were all 3 seconds long. Their maximum levels varied from 33 dB(A) to 80 dB(A). They had 16-bit resolution, with a sampling rate of 44.1kHz.

Apparatus

The sounds were played by an Apple MacPro 2x2.66 GHz Dual Core intel Xeon (Mac OS X v10.4 Tiger) workstation with a RME Fireface 800 sound card. The stimuli were amplified diotically over a pair of Sennheiser HD250 linear II headphones. Participants were seated in a double-walled IAC sound-isolation booth. Levels were calibrated using a Bruel & Kjær 2238 Mediator sound-level meter. The experiment was run using the PsiExp v3.4 experimentation environment including stimulus control, data recording, and graphical user interface [23]. The sounds were played with Cycling’74’s Max/MSP version 4.6.

Procedure

The experiment had two main steps. In the first step, the participants were provided, for each preset, with an interface allowing them to listen to the 10 sounds. For each set of 10 sounds, they had to write down what they thought to be the physical cause of the sounds (step 1.1: free description of the cause). Then (step 1.2: forced-choice experiment), they were provided with the same interface for each set of 10 sounds, but this time they had to choose among different categories of action (turning, shaking, rolling, rubbing, creaking, crumpling, tearing, falling, closing, breaking, hitting) and material (metal, glass, wood, plastic). These categories were selected from the results of the categorization experiments reported in Deliverable 4.1.

In the second part (step 2: estimation of height), the participants were told that the sounds they had heard had been produced by balls rolling in different vessels. They watched a video of different balls rolling in different bowls.

Then, in five sessions corresponding to the five presets, they had to estimate the height of the rolling ball with a slider allowing to move a picture of ball in a picture of a bowl (see Figure 3.2). The slider
ranged from 0 to 1, with 0 corresponding to the bottom of the bowl, and 1 to the rim. Each of the 10 sounds in each of the 5 presets was repeated twice (test/retest). The sounds were randomly ordered. Finally, participants comments were recorded, and they were asked whether they believed the sounds were recordings or real events or synthetic sounds.
3.1.2 Analysis

Step 1.1: free description of the cause

Table 3.1 reports for each of the five presets, the tally of participants who used the words “ball” (in French: “balle” or “boule”), “sphere” (“sphère”) or “marble” (“bille”), or “bowl”, (“bol”, “saladier”), “dish” (“plat”, “coupelle”, “soucoupe”), “plate” (“assiette”), “vase” (“vase”), “vessel” (“récipient”), or “jar” (“pot”) in their descriptions.

Thus, almost half of the participants have spontaneously mentioned a ball when asking to describe the cause of the sound. Figure 5.1 in Appendix reports the descriptions which did not include any synonymous of ball or vessel. In the table, the descriptions in bold can be fairly considered as describing a ball rolling in a vessel. The other descriptions describe a plate rolling on itself, objects vibrating, hitting, rubbing, bells, and even water. Overall these alternative descriptions seem to focus more on the micro-impacts provided by the model than on the rolling movement.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>“ball” and synonymous</th>
<th>“vessel” and synonymous</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>D</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3.1: Tally of words used to freely describe the sounds.

Step 1.2: forced choice of action and material

Figure 3.3 reports the histograms counting the number of answers in each category describing the actions causing the sounds. The most cited answers are, overall, “turning” and “rolling”, followed by “shaking”, “rubbing”.

Figure 3.4 reports the histograms counting the number of answers in each category describing the materials causing the sounds. For configuration A and E, participants identified mainly ”wood”. For configurations B, C and D, participants identified mainly metal and glass.

These figures, added to the free descriptions indicate that, overall, participants identified fairly well a small object rolling in a sort of bowl, and that the different presets were perceived as different materials. When the participants were afterwards told that the sounds had been made by balls rolling a bowls, none of them reported to be surprised or doubtful.

Step 2: estimation of height of the ball

Test/retest Figure 3.5 represents the distributions of the differences between the judgements made in the test/retest, averaged over the 10 sounds of each configuration. The differences lay overall around 0.1, even if some differences are as important as 0.5. Three participants were removed from subsequent analyses, because they had made estimations which differ by more than 0.25 on average for some configuration. The test and retest estimations were then averaged for the remaining participants.

Correlation between the subjects Figure 3.6 represents the correlations between the estimations of heights of the subjects. Overall, the estimations are correlated significantly (p<0.05). One participant displayed systematic negative correlations with the other participants in the case of configuration D, and low correlations in the other cases, suggesting that he did not interpret correctly the instructions. He was removed from subsequent analyses. Among the five configurations, configuration D lead to the best coherence between the subjects.
Figure 3.3: XP2.2.0. Histograms of the answers in the forced-choice experiment, for the action causing the sounds.

Estimations of height  Figure 3.7 represents the distributions of estimations of height, as a function of the height parameter, for each of the five configurations. Except for configuration A, the estimations of height increase with the height parameter. The variances of estimations are the smaller for configuration D.

Figure 3.8 represents the estimations of height, averaged over the participants, as a function of height parameter. The five configurations show an increase of the estimation of the height when the height parameter increases. The five curves display a rather linear behaviour except for the highest values of the parameter.

3.1.3 Discussion

These results are encouraging, for they show that 1. listeners can estimate properly the height of the ball (but it must be noted that this estimation depends a lot on the model parameters); 2. They have reported to find the sounds convincing (several of the participants have stated that the sounds originated from recordings). However the dynamics of the system appeared to be too much complicated to allow an user to control the sound in a reproducible way. Therefore, it was decided to design a new model: the ratcheted flywheel. The idea was to model the mechanical system (ratchet) occurring in a bicycle flywheel (see Figure 3.9).

ZHdK developed a Max/MSP patch based on Univerona’s SDT model of impact (see Deliverable 3.2, §4.1.3). With this sound model, the Spinotron behaves like a spinning top, on which one pumps to let it spin.
Figure 3.4: XP2.2.0 Histograms of the answers in the forced-choice experiment, for the material causing the sounds.

Figure 3.5: XP2.2.0. Representation of the distributions of the differences between test and retest for the five configurations, averaged over the 10 sounds of each configuration. The red line indicates the median, the box the lower and higher quartiles, the whiskers the maximum values, and the red crosses the outliers.
Figure 3.6: XP2.2.0. Representation of the correlations of the estimations of height between the participants. Black cells represent a positive significant correlation ($p<0.05$). Grey cells represent a non-significant correlation. White cells represent significant negative correlations.

Figure 3.7: XP2.2.0. Representation of the distributions of estimations of height, as a function of the height parameter, for each of the five configurations.
Figure 3.8: XP2.2.0. Estimations of height, averaged over the participants, as a function of height parameter.

Figure 3.9: XP2.2.1, 2.2.2 and 2.2.3. Principle of the ratchet mechanism.
4 Experiments with the ratcheted flywheel

4.1 XP2.2.1 Perception of the speed of the ratchet

This experiment is similar to experiment 2.2.0, except that the sounds are the sounds of a ratchet turning instead of the sound of a ball turning in a bowl, and that the participants have to estimate the speed of the ratchet, instead of the sound of the ball.

4.1.1 Method

Participants

Nineteen participants (12 women and 7 men) volunteered as listeners and were paid for their participation. They were aged from 19 to 42 years old (median: 23.5 years old). All reported normal hearing. Four of them reported high skill in music or sound analysis (professional musicians, musicologists, sound engineers, acousticians). The other 15 were considered as naive. The participants were all French native speakers or demonstrated high skills in French.

Stimuli

The sounds originated from the synthesis patches developed by ZHdK, based on UNIVERONA’s SDT model of impact (impact_inertialb). The synthesis was made to simulate the sound of a ratchet turning. Three presets of parameters were used ("B", "G", "F"), corresponding roughly to three different materials (woods, with more or less resonance). The parameter values for these presets are listed in Table 5.2. For each parameter preset, sounds were created, corresponding to 13 different speeds of the ratchet (0.08, 0.16, 0.24, 0.32, 0.4, 0.48, 0.56, 0.64, 0.72, 0.80, 0.88, 0.96, 1.04). The sounds were all between 3 and 4 seconds long. Their maximum levels varied from 47 dB(A) and 65 dB(A). They had 16-bit resolution, with a sampling rate of 44.1kHz.

Apparatus

The sounds were played by a Apple Macintosh Mac Pro 2x2.5GHz PPC G5 (Mac OS X v10.4 .11Tiger) workstation with a RME Fireface 400 sound card. The stimuli were amplified by a Yamaha P2075 amplifier diotically over a pair of Sennheiser HD250 linear II headphones. Participants were seated in a double-walled IAC sound-isolation booth. Levels were calibrated using a Brüel & Kjær 2238 Mediator sound-level meter. The experiment was run using the PsiExp v3.4 experimentation environment including stimulus control, data recording, and graphical user interface [23]. The sounds were played with Cycling’74’s Max/MSP version 4.6.

Procedure

The procedure was the same as in experiment 2.2.0. The experiment had two main steps. In the first step (step 1: description of the cause), the participants were provided, for each preset, with an interface allowing them to listen to the 13 sounds. They could listen to the sounds as many times as they wished. For each of the 3 presets, they had to write down what they thought to be the physical cause common to all the 13 sounds (step 1.1: free description of the cause). Then (step 1.2: forced-choice experiment), they were provided with the same interface for each set of 13 sounds, but this time they had too choose among different categories of action (turning, shaking, rolling, rubbing, creaking,
crumpling, tearing, falling, closing, breaking, hitting) and material (metal, glass, wood, plastic). They could choose several categories. These categories were selected from the results of the categorization experiments reported in Deliverable 4.1.

In the second part (step 2: estimation of the speed), the participants were told that the sounds they had heard had been produced by ratchets turning at different speeds. Then, in three sessions corresponding to the three presets, they had to estimate the speed with a slider. Each of the 13 sounds in each of the 3 presets was repeated twice (test/retest). At the beginning of each session, the participants were allowed to listen to all the sounds of the preset. The sounds were randomly ordered within each session, and the order of the sessions was randomly assigned to each participant.

4.1.2 Analysis

Step 1.1: free description of the cause

Only one participant spontaneously described the sounds has being caused by a wheel or a ratchet. Another participant described the sounds with Preset B as being caused by a “metallic mechanism”. All the other participants described the sounds either as something bouncing or being hit or struck (see the descriptions of all participants in Figure 5.2 in the Appendices). Thirteen participants among the 19 (68 %) reported that they believed the sounds were synthetic. Six among the 19 (32 %) reported that the sounds were recordings of real events.

Step 1.2: forced-choice of the cause

Figure 4.1 reports the histograms counting the number of answers in each category describing the materials causing the sounds. For configuration B participants identified mainly ”wood”. For configurations F and G, participants did not agree on a material. Almost as many of them identified wood, plastic or metal. Whereas the confusion between plastic and wood is not surprising (see the paragraph on the perception of structural properties of sound sources in Deliverable 4.1), the confusion between metal on the one hand, and wood and plastic on the other hand indicate that the chosen presets did not lead to a precise impression of a given material.

Figure 4.2 reports the histograms counting the number of answers in each category describing the actions causing the sounds. For the three presets, participants have mainly reported that the sounds is caused by something “hitting” or “falling”. Hence, these results combined with the results of the free description task indicate that the participants did not hear a turning wheel or ratchet.

Step 1.2: estimation of the speed

Test/retest comparison and correlation between the participants As in experiment 2.2.0, the differences between the evaluated speed in the tests and the retests is on average 0.1, which is a fair consistency. Therefore the test and retest scores are averaged.

The estimations of speed produced by all the participants but one are correlated with a statistical significance $< 0.01$. The remaining participant is correlated with the other ones with a statistical significance $< 0.05$. The estimations of speed are therefore consistent.

Estimation of speed Figure 4.3 represents the dispersions of the estimated speed as a function of the speed parameter, for the three presets. The estimations range from 0 to 1 (i.e. full scale). Overall, the estimated speed increases when the speed parameter increases. The dispersion is larger at the center of scale than at the extremes of the scale, because of a typical ceiling effect. The dispersion is homogeneous across the 3 presets. The dispersion is much smaller with these sounds than with the ball/bowl sounds in experiment 2.2.0 (see Figure 3.7), indicating that the participants were more consistent in estimating the speed of the ratchet than the height of the ball.
Figure 4.1: XP2.2.1. Histograms of the answers in the forced-choice experiment, for the material causing the sounds.

Figure 4.2: XP2.2.1. Histograms of the answers in the forced-choice experiment, for the actions causing the sounds.

Figure 4.4 represents the estimated speed, averaged across the participants, for the three presets. Two aspects are worth noticing. First, the estimation of speed is independent of the preset. Indeed,
and unlike the ball/bowl sounds, the three curves are very similar. Second. The speed parameter vs. estimated speed curves are quasi-linear from values of the speed parameter between 0.25 and 0.95. This latter result is important, for it will be useful to tune the sounds used in the Spinotron.

Figure 4.4: XP2.2.1. Estimated speed, averaged over all the participants, for the three presets.

4.1.3 Discussion

The results of this experiment are of two natures: they adress the issues of what is perceived with the sounds intended to mimic a ratchet sound, and the issue of the perception of the speed of the ratchet.

The results of the first part of this experiment (free description, and forced-choice of the actions and objects causing the sounds) clearly indicates that the listeners did not get the impression of a wheel or
a ratchet turning. Rather, they reported having heard something hitting, or something bouncing. One explanation of this result might be that the sounds used here were recordings of the synthesis patch corresponding to a constant speed. Therefore, the sounds were only a succession of impacts, without any specific temporal pattern that could have act as a cue: in these cases, the specific dynamics of a wheel turning (and particularly, the effect of the inertia during the acceleration and deceleration phase) was actually not embedded in the sounds. It is therefore not surprising that the participants reported that the sounds were caused by an object being periodically hit, which was actually how the patch worked in the case of constant speed sounds.

The results of the second part of the experiment (estimation of the speed) show that the listeners can fairly estimate the speed of the ratchet, and indicate the range in which this estimation is linear, with respect to the speed parameter. Furthermore, the results show that the estimation is not influenced by the preset (material) used (conversely to the perception of the height of the ball in the bowl). Together, these results indicate that it is possible to use the ratchet patch in the Spinotron if one wants to use the perceived speed of the ratchet as information conveyed to the user: he would perceived the variations of the speed parameter almost without distortion.

4.2 XP2.2.2 Selecting an appropriate preset

The goal of experiment 2.2.2 is to select presets of the ratchet patch that improve the perception of a ratchet mechanism. For the results of XP2.2.1 suggested that listeners did not perceived anything turning because we used sounds with a constant speed, the sounds used in experiment 2.2.2 will be recordings of the ratchet patch that specifically include transient behaviors (accelerations, decelerations).

4.2.1 Method

Participants Thirty-six participants (20 women and 16 men) volunteered as listeners and were paid for their participation. They were aged from 22 to 51 years old (median: 29 years old). All reported normal hearing. Thirteen of them reported skills in music or sound analysis (musicians, musicologists, sound engineers, acousticians). The other 15 were considered as naive. The participants were all French native speakers or demonstrated high skills in French.

Stimuli Five presets of the ratchet patch were used (“B”, “G”, “1”, “2”, “3”). Presets “B” and “G” were used in XP2.2.1. Presets “1”, “2” and “3” were specifically created by ZHdK to give the impression of a tiny mechanism. The parameter values of the 5 presets are listed in Table 5.2. There were two groups of sounds. For each preset there were 4 sounds corresponding to a constant speed of the ratchet, and 4 sounds corresponding to 4 different patterns of acceleration and deceleration. The sounds were all between 3 and 4 seconds long. Their maximum levels varied from 50 dB(A) and 66 dB(A). They had 16-bit resolution, with a sampling rate of 44.1kHz.

Apparatus The apparatus is the same as in XP2.2.1.

Procedure The participants were split into two groups: one group (18 participants) listened only to the sounds corresponding to a ratchet turning a constant speed. The other group (18 participants) listened only to sounds from a ratchet with a time evolving speed.

The experiment had four steps. In the first step (step 1: free description of the cause), the participants were provided, for each preset, with an interface allowing them to listen to the 4 sounds. They could listen to the sounds as many times as they wished. For each of the 5 presets, they had to write down what they thought to be the physical cause common to all the 4 sounds. Then (step 2: free description of actions and objects), they were provided with the same interface for each set of 4 sounds, but this time they had too freely describe what they thought to be the actions and the
objects causing the sounds in each preset. Then in step 3 (forced-choice of actions and materials),
they had to choose among different proposal of actions (vibrating, bouncing, banging together, hit-
ting, falling, going clickety-clack, turning, shaking, rolling) and materials (metal, glass, wood, plastic):
These categories were the same as in XP2.2.1 except that the actions rubbing, creaking, crumpling,
tearing, closing, breaking were removed, and that the actions vibrating (“vibrer”), banging together
(“entrechoquer”) and going clickety-clack (“cliqueter”) were added. These changes were made to better
fit with the answers provided in XP2.2.1 and with the kind of sounds used. Especially, the expression
going clickety-clack was thought to describe precisely the sound of a small metallic ratchet. Finally
in step 4 (portrait selection), the participants were provided, for each of the 5 presets, with a series
of 9 written “portraits”, and had to choose among these portrait which one(s) they tought to better
correspond with the sounds in the preset. These portraits were:

- A saucepan is being hit with a spoon (“On frappe avec une cuillère sur une casserole”)
- A ball is bouncing (“Une bille rebondit”)
- Water is dripping onto a vessel (“Des gouttes d’eau tombent dans un récipient”)
- A percussion is being struck (“On frappe avec des baguettes sur une percussion”)
- A ratchet is going clickety-clack (“Une roue dentée cliquette”)
- Finger tapping (“On tape des doigts”)
- A casino roulette is turning (“Une roulette de casino tourne”)
- A gear is turning (“Un engrenage tourne”)

These portraits were partly built from the results of the free verbalisation in XP2.2.1, partly from
what we thought to best describe the mechanism of the ratchet.

In each step the order of the presets was randomized, and the order of the display of the sounds
within each preset was also randomized.

4.2.2 Analysis

Free descriptions  Figures 5.3 and 5.4 in appendix report an example of the free descriptions for
the group of participants listening only to the sounds with a constant speed, and for the group of
participants listening only the sounds with an evolving speed. In both cases, only a few descriptions
mention a ratchet or a similar mechanism.

Figures 5.5 and 5.6 in appendix report the free descriptions of actions and objects for both groups
of participants. It can be noticed that presets “2” and “3” lead to more descriptions evoking a ratchet
or a similar mechanism than the other presets.

Selection of actions and objects  Figure 4.5 represents the histograms of the materials selected by
the two groups of participants. It must noted that the participants could select several materials.
On average, each participant selected 1.3 materials. Post-experimental interviews revealed that they
selected two different materials to indicate the interaction of two objects made out of two different
materials (e.g. metal on wood). There are not many differences between the two groups, indicating
that the temporal patterns of the sounds had only a little influence on the perception of the material
of theses sounds. Among the 3 new parameter settings, 1 is perceived as the sound of something made
out of metal or glass, 2 is mainly perceived as the sound of an object made out of metal or plastic,
and 3 as made out of wood. The answers are spread over the categories for parameter settings B and
G. It has to be noticed that, compared to the presets B, F and G tested in XP2.2.1, the distributions
of answers are more concentrated in one material. This indicates that these new presets give a clearer
impression of a specific material. This highlights the difficulty of creating a clear impression of a given
material with the SDT toolbox. Using a more systematic approach in the design of the sounds, as
described e.g. in [11] would have probably led to more robust results.

Figure 4.6 represents the histograms of the actions. Overall, it can be observed that the proportion
of answers “hitting”, which is very high for every presets for the group of participants hearing the
sounds with a constant speed, is much smaller for the group of participants hearing the sounds with
an evolving speed. For example, for preset G, the most cited action is “hitting” for the first group
Selection of portraits Figure 4.7 represents the histograms of the portraits selected by the participants for each of the presets and each of the groups of participants. The differences between the 2 groups are not easy to interpret. It must noted however that the “ratchet” portrait was most selected for preset 2.

4.2.3 Discussion

Some general trends emerged from this experiment. First of all, letting listeners listen to sounds with an evolving speed of the ratchet instead of a constant speed leads to a better perception of the mechanism of the ratchet, at least for the presets for which listeners perceive a ratchet. Second, the perception of the material for the 3 new presets is much more clear than for the previous presets. Finally, these results lead us to select the preset 2 for the Spinotron: listeners described the action causing these sounds mainly as “going clickety-clak” (in French: “cliqueter”), which is probably the best description of a ratchet sound, and they also selected the portrait corresponding to the ratchet. For these reasons, we will choose the preset 2 in the following experiment.
4.3 XP2.2.3 Testing the manipulation of the device

XP2.2.1 has shown that the ratchet model developed by ZHdK allow listeners to perceive the speed of the ratchet with a fair accuracy. XP2.2.2 has allowed to select a preset a parameters that made sounds roughly perceived as a mechanism similar to ratchet. In XP2.2.3, the ratchet model is implemented into the Spinotron developed by ZHdK (see Deliverable 3.2, section 4). Therefore, in this experiment, the participants will not listen passively to the sounds, but manipulate the device to make the sounds. The experiment will investigate how the manipulation of the device influences what the users perceive, and how the sounds may guide the user in manipulating the device. This experiment is therefore a first step into the study of sonic interactions.

Central to XP2.2.3 is the task that the users have to perform with the Spinotron. This task amounts in pumping the Spinotron so as to maintain the speed of the ratchet (the speed of the ratchet is communicated by the sounds of the ratchet) at a constant speed.

Another question raised by the manipulation of an interactive sonic device is: “how the dynamics (gesture/sound relationship) of the model might influence the performance of the users?”. To investigate this question, three dynamical modes designed by ZHdK will be tested in XP2.2.3: a “continuous” mode, corresponding to the physical (“natural”) behaviour of the ratchet, and a “quantized” and a “discrete” modes, corresponding to simplifications of the physical model. Even if the quantized and discrete cases are much more easily to manipulate because of their simple behaviour, it is expected that the continuous mode will be learned more easy by the listeners, because it corresponds to a physical behaviour, probably often encountered by the users in their daily experience.
Figure 4.7: Histograms of the portraits selected by the participants in XP2.2.2.

In summary, XP2.2.3 will investigate several questions/hypotheses:
- Does the manipulation of the device change the perceived cause of the sounds?
- Does the sound guide the users in performing the task?
- Is the physical dynamics of the device learned more quickly than the simplified behaviours?

4.3.1 Manipulating the Spinotron: designing the tasks

In order to study how the functionality of the Spinotron might be measured, ZhdK defined three modes of interacting with the Spinotron, corresponding to 3 dynamical modes of the ratchet:
- The continuous mode (c): in this case, the Spinotron behaves with the regular dynamics of the ratchet
- The quantized model (q): in this case, the Spinotron behaves with the regular dynamics of the ratchet, except that the speed of the ratchet is quantized. It can only take 4 discrete values (0, 0.33, 0.66 and 1)
- The discrete mode (d): this case is similar to the quantized model, except that the ratchet can turn with 6 different speeds (0, 0.21, 0.42, 0.63, 0. 84, 1.08), and that instead of taking into account the torque generated by the continuous pumping on the Spinotron, the model only counts how many times the Spinotron was pumped down per second.

The task to be achieved by the user is to pump so as to maintain the speed of the ratchet in a target area. The target area is 0.65-0.75. This target area is chosen, and the model is tuned in such a way that, independently of the mode of interaction, the target area can be reached by pumping regularly
the Spinotron at a pace of 3 pumping/s.

4.3.2 Method

Participants  Forty participants (25 women and 15 men) volunteered as listeners and were paid for
their participation. They were aged from 19 to 57 years old (median: 29 years old). All reported normal
hearing. The participants were all French native speakers or demonstrated high skills in French.

Apparatus   The apparatus was the same as in XP2.2.0 except than the sounds were played at the
same time through a Yamaha P2075 amplifier to a pair a Tannoy Reveal loudspeakers and a pair
of Beyerdynamic DT770 headphones. The headphones were used to mask the natural sound of the
Spinotron, and the loudspeakers were used during the demonstrations phases, when the experimenter
had to demonstrate the Spinotron to the participant. The participants interacted through an Elo Touchsystems Intuitive touch screen (they did not use the keyboard nor the mouse).

Stimuli and dynamics of the system   The stimuli were generated in real-time by the Max/MSP
ratchet patch provided by ZHdK on the basis of the SDT environment provided by UNIVERONUM,
when participants pumped the Spinotron.

Procedure   The procedure is summarized in Figure 4.8.

First, the participants were divided in 2 groups. The first group (N=22) did the experiment with
the sounds turned on, whereas the other group did the experiment with the sounds turned off (N=18).
The procedure had 2 main parts. The first part (phase 1: description) was only done by the first group.
In this part, the users had to describe the sounds of the Spinotron with the continuous dynamical
mode. They had to describe and select actions and materials, and to choose among 9 portraits, as in
XP 2.2.2. They were allowed to manipulate the Spinotron as long as they wished. Only the 6 groups
using the Spinotron with the sounds did this part.

The second part was the manipulation part. This part was done by the two groups of participants,
except 4 participants of the first group who encountered a technical problem. There was therefore 36
participants in part 2 (18 with the sounds on, 18 with the sounds off). For each of the three dynamical
modes, there were 3 phases. In phase 2.1 (a priori evaluation), the participants were required to judge
the manipulation of the Spinotron on three continuous scales: easiness, preference and naturalness.
The easiness scale corresponded to the question: “Judge how easy is the use of the device (in French:
“Jugez de la facilité d’utilisation du dispositif”), and had two labels at both ends: “Very difficult”
 (“très difficile”) and ”very easy” (“très facile”). The preference scale corresponded to the question:
“Evaluate how you appraise the device” (“Evaluez votre appréciation du dispositif”), with the labels
“I do not like it at all” (“je n’aime pas tu tout”) and “I like it very much” (“j’aime beaucoup”) at
both ends. The naturalness scale corresponded to the question: “Do you think the sound is natural?”
In phase 2.2 (performance) they had to manipulate the Spinotron so as to maintain a target constant speed of the ratchet (see below). This phase was made of 12 trials. Each trial was made of a training step, and test step. In each training step, a visual indicator with three colors indicated to the participants whether the speed of the ratchet was below the target speed, within the target, or above the target. During each test step, the participants did not receive any visual feedback. The training and test steps were 6 seconds long, and were initiated by a countdown, to allow the participants to get their hands on the Spinotron. Before phase 2.2, the procedure was demonstrated by the experimenter (with different sounds, and a different target). Figure 4.9 shows a participant performing the task with Spinotron.

![Figure 4.9: A participant pumping the Spinotron.](image)

In phase 2.3 (a posteriori evaluation), the participants were required to judge the manipulation of the Spinotron on the same three scales as in phase 2.1.

There were 6 combinations of order of the dynamical modes (c/d/q, c/q/d, d/c/q, d/c/q, q/c/d, q/d/c). In each of the two groups, 3 participants were randomly assigned to each of the orders. Any possible effect of the orders will not be considered in the following analyses.

### 4.3.3 Analysis

**Descriptions of the object and of the action**

Figure 5.7 in the appendix reports the descriptions of the objects and actions provided by the listeners. Again, only a few of them describe a ratchet or a similar mechanism. It can be noted that some subjects tried to describe how their own action on the Spinotron might have caused the sounds (e.g. “c’est un roulis qui fait office de levier quand on appui la partie supérieure de l’objet”).

[26]
Selection of materials, interactions and portraits

Figure 4.10 reports the distributions of materials selected by the participants. In this figure, the histograms from the previous experiment (XP2.2.2) have also been represented. A Pearson $\chi^2$ test reveals that the distributions of answers between the two groups of participants in XP2.2.2 are not significantly different ($\chi^2(2,N=18)=1.30$, $p=0.35$). However the results of these two group are significantly different from the results of XP2.2.3 (constant speed vs. XP2.2.3: $\chi^2(3,N=18)=12.6$, $p<0.01$; evolving speed vs. XP2.2.3: $\chi^2(3,N=18)=18.4$, $p<0.01$). Indeed, whereas the participants in XP2.2.2 described the sounds mainly as plastic and metal, the participants in XP2.2.3 described the sounds mainly as metal and glass.

Figure 4.10: Histograms of the materials selected by the participants in XP2.2.2 and XP2.2.3.

Figure 4.11 reports the distributions of actions selected by the participants to describe the cause of the Spinotron. A Pearson $\chi^2$ test reveals that the distributions of answers between the two groups of participants in XP2.2.2 are not significantly different ($\chi^2(8,N=18)=8.94$, $p=0.35$). The distributions from XP2.2.2 and XP2.2.3 are not significantly different as well (constant speed vs. XP2.2.3: $\chi^2(8,N=18)=10.2$, $p=0.25$; evolving speed vs. XP2.2.3: $\chi^2(7,N=18)=13.4$, $p=0.06$). The high proportion of “going clickety-clack” is however noticeably high in the 3 cases.

Figure 4.12 reports the distributions of portraits. A Pearson $\chi^2$ test reveals that the distributions of answers between the two groups of participants in XP2.2.2 are not significantly different ($\chi^2(5,N=18)=2.37$, $p=0.80$). However the results of these two group are significantly different from the results of XP2.2.3 (constant speed vs. Experiment 3: $\chi^2(4,N=18)=14.7$, $p<0.05$; evolving speed vs. XP2.2.3: $\chi^2(4,N=18)=10.6$, $p<0.05$). Indeed, the participants in XP2.2.3 have described the sounds more often as a “bouncing ball” than a “ratchet going clickety clack”, while it was the opposite in XP2.2.2.

A priori and a posteriori evaluations of the Spinotron

Even if the participants evaluated the 3 dynamical modes (continuous, discrete and quantized) of the Spinotron, only the data from the last dynamical mode evaluated by each participant were analyzed. Indeed, only in the last run of the experiment each participant had already experimented the 3 modes,
and was therefore able to compare these three modes. Therefore, it can be assumed only in this last evaluation that the participants have the same references.

Figure 4.13 represents the mean values and standard deviations for the 3 scales (easiness, preference, naturalness), and for the 3 modes of the Spinotron evaluated before (“a priori”) and after (“a posteriori”). A lot of these values lay around 50 %, but there are interesting differences to notice. Table
4.1 reports the results of the Student t tests comparing the a priori and posteriori evaluation on the 3 scales for the 3 modes. For the discrete and quantized modes, the mean values are around 50 % for the 3 scales, and do not change between the a priori and the a posteriori evaluations. However there are differences for the continuous mode on the easiness and naturalness scales: after the performance task, participants judge the Spinotron less easy and less natural than when they were freely manipulating it.

Table 4.1: Results of the Student t tests comparing the a priori and posteriori evaluation on 3 scales of the three dynamics of the Spinotron.

<table>
<thead>
<tr>
<th>Dynamics</th>
<th>Easiness</th>
<th>Preference</th>
<th>Naturalness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete</td>
<td>t(10)=1.62, p=0.068</td>
<td>t(10)=0.22, p=0.69</td>
<td>t(10)=0.41, p=0.31</td>
</tr>
<tr>
<td>Continuous</td>
<td>t(10)=-2.45, p=0.017*</td>
<td>t(10)=-0.97, p=0.18</td>
<td>t(10)=2.20, p=0.026*</td>
</tr>
<tr>
<td>Quantized</td>
<td>t(10)=-0.75, p=0.76</td>
<td>t(10)=-0.51, p=0.69</td>
<td>t(10)=0.45, p=0.33</td>
</tr>
</tbody>
</table>

Figure 4.13: XP2.2.3. Mean and standard deviation values for the three scales (easiness, preference, naturalness), and for the 3 modes of the Spinotron evaluated before (“a priori”) and after (“a posteriori”).

Performances

Defining a performance measure Because the 3 modes of the model used in the Spinotron lead to very different behaviors of the ratchet, it is not simple to define a performance measure suitable with the 3 modes. Indeed, while the speed of the ratchet evolves continuously in the continuous mode, it can only have discrete values in the discrete and quantized modes. This can be seen on Figure 4.14 representing the speed maintained by a participant in the 3 modes. For example, using the distance between the target and the actual speed would not be a good measure of performance, because in the case of the continuous dynamics, this distance depends only on the user’s performance, while in the other cases, it depends also on the quantization steps. Therefore it was decided to count how long the speed of the ratchet stayed within the target area as the measure of performance.
Analysis of variance. Eighteen participants performed the experiment with sounds (audio turned on), and eighteen without sound (audio turned off). To prevent from a learning effect between the 3 modes, only the results from the first run were used. Therefore there are 6 groups of 6 participants: continuous with sounds, discrete with sounds, quantized with sounds, continuous without sound, discrete without sound, quantized without sound. Formally, the experiment has a 2 between-subjects 1 within-subject repeated measure design, with the audio (on/off) and the dynamical mode (continuous, quantized, discrete) as the between subjects factors, and the number of trials (1 to 12) as the within-subject factor. The dependant variable is the performance score.

The data are submitted to a 2x1 repeated measure ANOVA. A Mauchly’s test reveals that the co-variance matrix of the dependant variable cannot be assumed to be spherical or circular (W(65)=0.014, p<0.001). Therefore, in the analysis the number of degree of freedom is corrected with the Geisser-Greenhouse correction (\(\epsilon=0.606\)). Table 4.2 reports the statistics of the ANOVA. With an alpha value of 0.01, the principal effects of audio, dynamical mode and number of trials are all significant. No interaction is significant.

Figure 4.15 represents the average values of the performances of the participants as a function of the number of trials, the dynamical mode, and the use of sounds. The effect of audio is significant (F(1,35)=7.821, p=0.009), indicating that the performances are significantly better when users could listen to the sounds of the Spinotron. Hearing the sound of the ratchet has therefore helped the participants to perform the task. The effect of the dynamical mode is also significant (F(2,70)=7.941, p=0.002), indicating that the performance are also better with the quantized and discrete modes than with continuous mode. Because of the quantification of the speed, the task was therefore easier in these modes, and more difficult in the continuous. Indeed, in this latter mode, any variation in the way of pumping resulted in a variation of the change of the speed of the ratchet. This mode was the most sensible. The effect of the number of trials is significant (F(11,385)=4.920, GG<0.000), indicating that the performance increased with the number of trials: the participants have learned how to use the Spinotron across the trials. However, the \(\eta^2\) values indicate the number of trials have contributed the less to the variance in the data, compared to the effect of the dynamical mode and of the audio. The differences in the performances due to the different dynamical modes were indeed larger than the differences due to the learning across the trials.

The right panel of Figure 4.15, and the absence of significant interaction between mode and number of trials indicate that the speed of learning across the trials was the same for the three dynamical
Table 4.2: Analysis of variance for XP2.2.3

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>$F$</th>
<th>η²</th>
<th>$p$</th>
<th>GG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audio (A)</td>
<td>1</td>
<td>7.821</td>
<td>0.207</td>
<td>0.009**</td>
<td></td>
</tr>
<tr>
<td>Mode (M)</td>
<td>2</td>
<td>7.941</td>
<td>0.346</td>
<td>0.002**</td>
<td></td>
</tr>
<tr>
<td>A x M</td>
<td>2</td>
<td>2.078</td>
<td>0.122</td>
<td>0.143</td>
<td></td>
</tr>
<tr>
<td>$S$ within-group error</td>
<td>30</td>
<td>(0.286)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trials (T)</td>
<td>11</td>
<td>4.920</td>
<td>0.141</td>
<td>0.000**</td>
<td>0.000**</td>
</tr>
<tr>
<td>T x A</td>
<td>11</td>
<td>1.398</td>
<td>0.045</td>
<td>0.172</td>
<td>0.211</td>
</tr>
<tr>
<td>T x M</td>
<td>22</td>
<td>1.210</td>
<td>0.075</td>
<td>0.236</td>
<td>0.273</td>
</tr>
<tr>
<td>T x A x M</td>
<td>22</td>
<td>1.106</td>
<td>0.069</td>
<td>0.338</td>
<td>0.355</td>
</tr>
<tr>
<td>T x $S$ within-group error</td>
<td>330</td>
<td>(0.021)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent mean square errors. $S = subjects$. **$p < 0.01$.**

$GG = probability after Geisser-Greenhouse correction of the degree of freedom.$

modes. Conversely to the hypothesis, the users have not learned the continuous dynamical mode (physical model) faster than the the two other modes.

Figure 4.16 represents in three different panels corresponding to the three dynamical modes the effect of the sounds of the Spinotron on the performance. This figure shows that whereas there is a clear difference between the performance with and without sounds in the case of the discrete mode, the conclusion is not obvious in the case of the continuous mode. In this case, the performance do not seem to increase with the number of trials when the users could not listen to the sound of the Spinotron. With the group of participants who could listen to the sounds, the performance increase with the number of trials, but very slowly, apparently only after 7 trials. This effect is not significant (a significant effect of the three-way interaction T x A x M would be required), but this might be explained by a too small number of trials that prevent from a significant increase of performance, and by the large inter-individual differences.

Indeed, there are large inter-individual differences. Figure 4.17 represents the individual performances of 2 participants belonging to the group of participants using the continuous mode with sounds. Whereas the participant 2 was able to continuously increase his performance after a few trials, participant seems to have performed randomly. Even after the 12 trials, he does not seem to be able to maintain to good performance. Therefore, the average values used in the ANOVA collect data from very different behaviours.

#### 4.3.4 Discussion

Experiment 2.2.3 is a large experiment that has aimed at testing many hypotheses.

The first part of the experiment studied how the participants described the cause of the sounds, when they had to freely manipulate the Spinotron. Particularly, the results were compared to the results of XP2.2.2, in which the participants could hear the sounds only passively (the sounds were not caused by their manipulation of the device). The comparisons show that manipulating the device
Figure 4.15: XP2.2.3. Average values of the performances of the participants as a function of the number of trials, the dynamical mode, and the use of sounds.

has changed the material reported by the participants: whereas in XP2.2.2, the participants mainly described the sounds as caused by some objects made out of plastic or metal, they report in XP2.2.3 objects made out of metal or glass. Because the sounds were designed to sound like metal, this results indicates that manipulating the device has helped the participants to perceive the intended model. Comparing the actions and the portraits selected in both experiments shows that manipulating the device does not really change how the listeners perceived the interaction. In both case, there is an ambiguity between a ratchet going clickety-clack, and objects bouncing or banging together.

In the second part, the participants had to perform a defined task: pumping the Spinotron so as to maintain the speed of the ratchet constant. There were 3 dynamical modes of the ratchet mode: continuous (physical behaviour) of the ratchet, quantized and discrete. The continuous model provided the more precise control on the sound, and was therefore the more difficult to control. The quantized and discrete models provided limited, arbitrary, but easier controls of the sounds.

The participants had to judge the device on three scales (easiness, preference and naturalness), before and after having performed the task (a priori and a posteriori evaluations). For the quantized and the discrete modes, there was not any difference between the two evaluations. For the continuous mode, the participants found after the task the device less natural and less easy than before performing the task. However significant, the differences are small, and for the evaluation all lay around the mid point of the scales, it might be suspected that the participants did not really know what to evaluate with the scales.

The main part of XP2.2.3 consisted in the performance task. Participants had to pump the Spinotron so as to maintain a constant speed of the ratchet. They alternated learning phases, in which they were provided with a visual feedback, and test phases in which there was not any visual feedback. There were 12 trials. There was a group of participants who could not hear the sounds. Therefore, they could only do the task by focusing on their gesture. The other group of participants could hear the sounds of the ratchet model. Comparing the performance of the two groups shows that hearing
the sound of the ratchet led to better performance, indicating that the sounds actually guided the user to adjust their gesture. The participants were split into 3 groups and provided with 1 of the 3 different dynamical modes. Comparing the performances for these 3 groups show that the performance
were better for the groups who used the quantized and discrete modes (these modes were the easiest). Comparing the increase of performance across the trials does not show however any difference between the three groups. Conversely to the hypotheses, participants have not learned the continuous mode faster than the other modes. It must be noted however that the number of trials was not sufficient in the continuous mode to observe a significant increase of performance, because the task was much more difficult in this case, and requires therefore much more training.
5 Conclusions

The experiments presented in this deliverable are a first step toward the development of methodologies to assess functional-aesthetic aspects of sonic interactive designs. Indeed, they were based on the manipulation of the Spinotron, designed by ZHdK, and sonified on the basis of the SDT synthesis toolbox, which is a sonic interactive prototype.

5.1 Summary of the experiments

In XP2.2.0, we studied the perception of the sounds generated by a model developed by ZHdK, synthesizing the sound of a ball rolling in a tilted bowl. The participants had to estimate the height of the ball in the bowl. The results showed that they identified a ball in a bowl, and could estimate the height with a fair accuracy. However, the dynamics of the model made too difficult to control with the Spinotron. It was therefore decided of use a model of ratcheted flywheel, set into rotation when pumping the Spinotron.

XP2.2.1 applied the same methodology to this model: participants had to estimate the speed of the ratchet rotating. Again, the results showed that the listeners were able to estimate the speed of the ratchet with a fair accuracy, within a certain range. The estimation of speed did not depend on the choice of the model parameters controlling the timbre (and therefore the perceived material) of the ratchet sounds.

XP2.2.2 was designed to select the model parameters that best give the impression of a ratchet turning. Indeed, several presets of parameters had been selected. Participants were required to select among different materials, interactions and portraits describing the cause of the sounds. The proposed materials, interactions and portrait had been built from verbalizations in XP2.2.1. There were two groups of participants: one group listened to sounds corresponding to steady speeds of the ratchet, and the other group listened to sounds corresponding to increasing and decreasing speeds of the ratchet. Comparing the two groups allows to conclude that the perception of a ratchet turning is reinforced when the listeners listen to the increasing and decreasing speeds of the ratchet: whereas in the case of steady speeds the sounds can be described as series of impacts, without any specific pattern that could identify the cause of these impacts, in the case of increasing and decreasing speeds, the listeners actually listen to the specific dynamics of the ratchet (inertia, damping), which provides more robust acoustic cues. The experiment also allowed to select the best set of parameters.

XP2.2.3 studied the manipulation of the Spinotron. The core of this experiment was a learning experiment. Across trials, participants had to learn how to manipulate the Spinotron so as to maintain a constant speed of the ratchet. One group of participant did the experiment without the sounds of the ratchet model in order to verify if the sounds really guide the user in performing the task. We studied the physical dynamics of the ratchet model, as well as simplified deviations from this dynamics, providing poorer, but simpler control on the sound. Participants were also required to assess the easiness and the naturalness in using the Spinotron, as well as their preference before and after having performed the learning experiment.

The results of XP2.2.3 showed that the sounds of the ratchet model really guided the users in maintaining a constant pumping pace. This is not a trivial result, for the task could be easily done without the sounds, only by learning the correct gesture, and for many participants had reported to have focused only on their gesture. They also showed that, whatever the dynamical mode used, the performance increased across the trials: the participants have learned how to manipulate the Spinotron. However the learning is not faster in the case of the physical dynamics. The participants...
have learned the device with the same speed, whatever the dynamical mode.

5.2 Discussion

Besides the results of these experiments, which are important for the design of sonic interactive prototypes, this series of experiments leads to many comments with regards to the development of a methodology to assess the functional-aesthetics aspects of sonic artifacts.

5.2.1 Selection of relevant sounds for the Spinotron

Studying how listeners describe the cause of the sounds has proven to be an efficient method to select the sounds that are to be used in the prototypes. The method of free verbalization do not provide in itself results that allow to select the relevant sounds (it is too time-consuming to analyze them systematically), but allows to choose descriptions (cause, interaction, portraits) that can be used in forced-choice experiments. These forced-choice experiments are much more easy to analyze, and allow to efficiently compare the perception of the cause of different sounds. It must be noted that these results highlight the difficulty to create sounds which have a clear identity in term of the perceived material. The systematic work done with NIPG [11] is therefore expected to help the systematic design of such sounds.

The results from the experiments reported in Deliverable 4.1 have shown the relevance of questioning listeners on the objects, and on the actions that they perceived as causing the sounds. Here we introduce a new type of forced-choice experiment: the selection of portraits.

5.2.2 Proposal for functional-aesthetic measurement

To assess the functional-aesthetical aspects of the interactive sonic devices, we have tested in these experiments different methods: forced-choice experiments, rating on scales, performance measurements.

Scales for functional and aesthetic assessment

Scaling methods were successful when evaluating the sounds passively (rating the height of the ball, the speed of the ratchet). In these cases, the judgements were magnitude estimation of a perceived intensity (height, speed). These experiments were therefore similar to traditional psychophysical experiments.

The a priori/a posteriori judgements of easiness, naturalness and preference on continuous scales were, on the other hand, not successful. Yet the results showed a significant decrease of estimated naturalness and easiness for the continuous dynamical mode the ratchet model after the performance task, all the judgements lay around 0.5. This suggests that the user have probably not known how to use these scales. Several explanations may be assumed. First, this can indicate that the questions (easiness, preference, naturalness) were not relevant to the users. Maybe because the questions were not well explained, or maybe because they were not relevant to the specific prototype they were using. Indeed, the principle of the Spinotron was to provide an interface implementing an abstract sonic interaction. Therefore the task to be done (maintaining a constant speed of a virtual wheel) was also rather abstract. Asking the participants how much they liked each dynamical variation of the model was probably something they had difficulties to answer. Similarly assessing the “naturalness” of an artifact that they knew to be electronic and computer-based made probably the question irrelevant to the participants.

Second, using continuous scales with two labels at the end is probably not a good procedure. Indeed, when presented with a scale from “I don’t like it at all” to “I like it very much”, and a prototype that they did not have specific reason to like “very much” or not to like “at all”, the participants may have simply used only a restricted range of the scale, “in between”. There are experimental procedures that
better suit such questions (category scales, etc.). They will be tested in on-going project, assessing the mutual influence of aesthetics and function of sonified keyboards.

Third, we have assumed that, in the last run of XP223, the participants were actually comparing the three dynamical modes when they were using the scales. This means that they would have to remember that previous modes that they had been manipulating in the previous runs. However, this might not be the case.

This lack of results is problematic, because it prevents us to draw conclusions on the mutual influence of aesthetic and functional aspects of the Spinotron. The “keyboard project” mentioned above is expected to provide such results.

**Performance measurement**

Conversely to the judgements of easiness, preference and naturalness on continuous scales, the measurement of performance in manipulating the Spinotron has provided very interesting data, for it has allowed to compare the three dynamical modes, and it has shown that the sound of the Spinotron really guided the users in pumping the Spinotron at a constant pace. Particularly, studying how the users learn the device allow to highlight fine behaviours. This kind of procedure is therefore expected to be very useful in studying the functionality of sonified artifacts. Another project done in collaboration with UNIVERONA during a MINET study visit on rhetorical earcons has also shown very interesting results by using the same kind of method.

There are however some issues. One of the most important is: how to choose a relevant performance measurement. Here, because the Spinotron is an abstract prototype, we were able to define the task that the users had to do, and a performance measurement that corresponded closely to the task. This might not be the case with real objects.
Bibliography


## Appendices

### Appendix A. Bowl/ball model parameters

<table>
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<th>Patch</th>
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Table 5.1: Parameters used in experiment 2.2.0
Figure 5.1: Descriptions of sounds not mentioning “ball” or “vessel.”

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<td>Action manuelle</td>
<td>Wood vibrating on metal (&quot;Du bois qui vibre sur du métal&quot;)</td>
<td>An object rolls, turns on glass (&quot;Un objet qui roule, tourne sur du verre.&quot;)</td>
<td>A wooden object hitting metal (percussion). (&quot;Un objet en bois qui tape/frappe sur du métal (percussion).&quot;)</td>
<td>Rapid percussions of an object with a support. (&quot;Percussion rapide d'une pièce avec un support&quot;)</td>
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<td>Action manuelle</td>
<td>Something cylindrical rolling with percussions on the metallic part (&quot;Roulement d'une pièce cylindrique avec percussion sur partie métallique&quot;)</td>
<td>A physical action agitating an object in a vessel (&quot;Agitation d'une pièce dans un contenant sous l'effet d'une action physique&quot;)</td>
<td>Contact of two materials through rolling (&quot;Contact d'entre deux matières par roulement&quot;)</td>
<td>An object vibrating on a silver wire (&quot;Vibration d'un objet sur un câble&quot;)</td>
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<td>Sons émis par un objet métallique vibrant</td>
<td>Bouncing water causing an object to vibrate (&quot;Des ondulations provoquant l'objet&quot;)</td>
<td>Electricity causing an object to vibrate (&quot;Electricité faisant vibrer un objet&quot;)</td>
<td>Alarm bell (&quot;Sonnerie d'alarme&quot;)</td>
<td>Impacts, Timbres of bells (&quot;Impacts - timbres de carillon&quot;)</td>
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<td>Sons émis par un objet métallique vibrant</td>
<td>A metallic bar passing on a grid (&quot;Une barre de fer qui passe sur une grille&quot;)</td>
<td>Self-initiation of a metallic noise, like a bell (&quot;Rend la sonorité de verre&quot;)</td>
<td>Metallic noise, like a bell (&quot;Rend la sonorité de verre&quot;)</td>
<td>Metallic noise, like a bell (&quot;Rend la sonorité de verre&quot;)</td>
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<td>Les sons sont lancés qui sont prêts à tomber</td>
<td>Something cylindrical rolling (&quot;Trou du métal qui frappe sur de la pierre&quot;)</td>
<td>A coin thrown, and just about to fall (&quot;Pièce de monnaie lancée qui est prête à tomber&quot;)</td>
<td>A coin thrown, and just about to fall (&quot;Pièce de monnaie lancée qui est prête à tomber&quot;)</td>
<td>A coin thrown, and just about to fall (&quot;Pièce de monnaie lancée qui est prête à tomber&quot;)</td>
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<tr>
<td>Du verre qui pivote sur lui-même sur de la terre</td>
<td>Like the sound of water, liquid passing through a mill, like a strange soft maker. The greater the flow is, the faster turns the mill, the lesser the flow, the slower turns the mill, without stopping. (&quot;On dirait comme un bruit d'eau, un liquide qui passe dans une moulteuse ; un peu comme une cafetière, une &quot;éolienne&quot; un peu bizarre ; plus il y a de débit, plus la moulinette tourne ; moins il y a de débit, moins la moulinette tourne sans s'arrêter.&quot;)</td>
<td>Use the other series. I really think that there is a flow of liquid, more or less fast, which triggers an mechanical mechanism, motor (&quot;Ce ressemble aux séries précédentes ; je pense qu'il y a vraiment un doublement de liquide plus ou moins rapide et que la déclenchement un mécanisme mécanique moteur qui suit le débit d'eau ; une dynamo&quot;)</td>
<td>Same noise as before, but with a higher pitch. Sound 5 has a drop at the end (&quot;Même bruit que précédemment mais en plus aigu avec le son 5 un groute à gauche vers la fin;&quot;)</td>
<td>Same noise as before, but the sound is lower in pitch, sourer. There are still different rhythms, like fast, there is a cracking on top of a metallic noise, like when one washes dishes, and water is dripping on a pan (&quot;Même bruit que précédemment sauf que le son est plus grave, plus aigre ; il y a toujours des différences de rythmes, lent, aiguë ; il y a un glissement en plus d'un bruit de métal comme on fait la vaisselle et que l'eau ou le robinet tombe sur une plaque par exemple&quot;)</td>
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<tr>
<td>A object rolling (&quot;Sans émis par un objet en rotation&quot;)</td>
<td>An object with friction, with different intensities (&quot;Sans émis par un objet en rotation avec des intensités différentes&quot;)</td>
<td>Same cause as previously, but with different frequencies and durations (&quot;Sans émis par une même cause que les précédentes à des fréquences et durées différentes&quot;)</td>
<td>A metallic object vibrating at different durations and frequencies (&quot;Sans émis par un objet vibrent métallique à durée et fréquences différentes&quot;)</td>
<td>A metallic object vibrating at different durations and frequencies (&quot;Sans émis par un objet vibrent métallique à durée et fréquences différentes&quot;)</td>
</tr>
<tr>
<td>An object rolling in glass, following a rhythm, with some impacts, safe from the sound 8 and the sound 10. The object is probably not round (&quot;Roulement d'un objet dans du verre suivant un rythme, avec quelques chocs, sans sur l'échantillon sonore 8 et grâce favorable sur le 10. L'objet qui roule, comme aux tests précédents ne doit pas être parfaitement rond.&quot;)</td>
<td>Like sound 1. There might be glass as well. (&quot;Même chose que pour le son 1. Il se pourrait qu'il y en ait aussi&quot;)</td>
<td>A small object rolling in a circular object, with more or less speed, on a roughly regular way. (&quot;Roulement d'un petit objet dans un objet en verre circulaire à plus ou moins grande vitesse et de façon à peu près régulière.&quot;)</td>
<td>An irregular rolling object in a circular object in resonating wood. Sometimes it reminds me of musical instruments, sometimes glass sounds emerge (&quot;Roulement d'un objet irrégulier dans un objet circulaire en bois resonant. A des moments, cela me fait penser à un frétement sur un instrument de musique longs cordes en bois, à d'autres, des sonorités de verre semble ressembler.&quot;)</td>
<td>An irregular rolling object in a circular object in resonating wood. Sometimes it reminds me of musical instruments, sometimes glass sounds emerge (&quot;Roulement d'un objet irrégulier dans un objet circulaire en bois resonant. A des moments, cela me fait penser à un frétement sur un instrument de musique longs cordes en bois, à d'autres, des sonorités de verre semble ressembler.&quot;)</td>
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<td>An object rolling in a narrow concrete canal (&quot;Roulement d'un objet dans un canal étroit en béton&quot;)</td>
<td>Back and forth of a small object in a circular object out of glass. The object is maybe not regular and has salient parts causing impacts, or the object is not perfectly circular, and has steep slopes. (&quot;Aller-retour dans un objet en verre circulaire d'un petit objet avec chocs. Peut être l'objet en plus de ne pas être régulier contient des parties plus saillantes provoquant les chocs, peut être l'objet n'est-il pas parfaitement circulaire et contient des rebords abrupts.&quot;)</td>
<td>A big mass - cylinder - following an average trajectory - speed. (&quot;Une grande masse - cylindre qui suit un trajet moyen-vitesse moyenne&quot;)</td>
<td>An object rolling in a metallic tube (&quot;Roulement d'un objet dans un tube métallique&quot;)</td>
<td>A metallic ball gliding on a grid (&quot;Une balle de fer qui glisse sur une grille&quot;)</td>
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## Appendix C. Ratchet model parameters

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Table 5.2: Parameters used in experiment 2.2.1, 2.2.2 and 2.2.3
Participants

1. Le son plus clair que le précédent.
2. percussif et basse, une seule vibration audible. On dirait un objet solide qui se déplace lentement sur une surface métallique. On note la présence d'harmoniques et d'overtones de fréquences variables.
3. Percussion d'un objet sur une surface métallique.
4. Un objet qui glisse sur une surface plastique.
5. Il s'agit d'un son criard, ressemblant à un objet en métaux.
6. Il s'agit d'un son criard, ressemblant à un objet en métaux.
7. Il s'agit d'un son criard, ressemblant à un objet en métaux.
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17. Il s'agit d'un son criard, ressemblant à un objet en métaux.
18. Il s'agit d'un son criard, ressemblant à un objet en métaux.
19. Il s'agit d'un son criard, ressemblant à un objet en métaux.
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<td>Meme impression que le son precedent, le son serait produit par un objet ou un insect en mouvement circulaire.</td>
<td>Je pense que le son a ete produit par un objet qu'on fait rouler sur les parois (en bois ?) d'un recipient. Meme impression de mouvement circulaire que les sons precedents.</td>
<td>Le son viendrait d'une bille en fer qu'on ferait rouler dans un recipient, il y a une impression de mouvement, comme si l'objet tournait en rond...</td>
<td>La production de ce son est assez difficile a comprendre (ca ne ressemble pas a un son naturel), peut-etre de la meme maniere que precedentement, le son est produit par une balle de ping pong qu'on fait tourner dans un recipient en verre ?</td>
<td></td>
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<tr>
<td>Meme impression que le son precedent, le son serait produit par un objet ou un insect en mouvement circulaire.</td>
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<td></td>
<td>le pense que le son a ete produit par une roue qu'on tourne, type roue de la fortune ? le son viendrait du caoutchouc (aiglet) peut etre en bois entre les sections.</td>
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<td></td>
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<tr>
<td>La surface de l'objet frappe n'est pas facilement identifiable : cela pourrait etre une peau (ou matière similaire) tendue, un objet en metal creux, de la ceramic (un bol...). Il est possible qu'il y ait quelque chose a l'interieur de l'objet frappe, comme du liquide ou un instrument, en petit quartier par contre. On entend un echo dans l'objet en lui meme qui est aussi audible de l'exterieur. L'echos est peut etre &quot;axial&quot; ou modifie par la presence de la surface a l'interieur.L'objet qui frappe est plus dur que l'objet frappe et de plus petite taille, d'où sa precision de &quot;tir&quot;.</td>
<td>L'objet frappe semble etre un instrument de musique tournant sur lui-meme, dans un tambour, ou une sorte de tambour, dans tous les cas, l'objet ressemble a un peu un tambour, un instrument.L'objet le plus dur ne ressemble pas assez dur et lourd pour etre en metal, l'objet frappe semble etre de taille moyenne, pas trop petit en tout cas.</td>
<td>Un objet renre en &quot;collision&quot; de façon reguliere avec un autre objet dont la surface semble en metal et qui parait en mouvement circulaire continu.L'objet qui frappe l'autre est de la meme nature que l'autre et certainement pas de la meme maniere. On peut entendre la boucle (desole) mais le fait que la boucle est toujours pareille pour la boucle (desole) mais ce fait ca donne l'impression d'un bec qui frappe sur du bois ou un djambe, ou une sorte d'insect en boucle.</td>
<td>Un objet solide frappant de façon plus ou moins rapide sur une surface elle aussi solide. On peut avoir l'impression qu'il rebondit contre cette surface. L'objet ressemblait a quelque chose de pointu et fixe qui a ete mis en contact avec la surface. Certains possedent de la surface que l'objet frappe ressemble a du bois, et que l'objet en lui meme doit etre construit dans une autre maniere, plus lourde, plus dur, etc. Il provoque une sorte d'echo sur le bois.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si un beat en boucle d'une cloche</td>
<td>petit tambour enregistrant dont on accorde le son ou le contretemps.</td>
<td>melange d'une cloche et d'un son qui ressemble a un insect, en boucle.</td>
<td>toujours parallele pour la boucle (desole) mais cette fina donne l'impression d'un bec qui frappe sur du bois ou un djambe, organe de la geule qui claque a l'interieur de la bouche ou le bec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mecanique tournant sur elle-meme avec un ergot heurtant une coupelle en cuivre</td>
<td>mecanique tournant sur elle-meme avec un ergot en metal heurtant une coupelle en cuivre</td>
<td>un son, un petit insect remet</td>
<td>mecanique tournant sur elle-meme avec un ergot heurtant une coupelle en cuivre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>percussion contre un support metallique, bille ou boule tapee sur une surface en metal.</td>
<td>percussion d'un objet peut etre en bois dans un recipient en metal, en tout cas dans un toit en metal concave.</td>
<td>percussion tres rapide de toutes petites billes mettalliques, sans oscillations.</td>
<td>percussion de deux petits objet, sertiment des boules, en bois, l'un contre l'autre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>je dirai une cuillere ou autre ustensile en bois frappant sur matiere mettallique layer</td>
<td>baguette de bois frappant sur bol de bois retourne</td>
<td>percussion plus ou moins rapide d'une tige en metal contre un support metalique plus fin, en tout cas qui vibre, comme pour un carillon ou une cloche ou une sonnette.</td>
<td>ce son sorte sure je dirais qu'il frappe avec une sorte de petit marteau ou meillet sur un plat en bois retourne</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.3: Free descriptions of the sounds in experiment 2.2.2, for the sounds corresponding to a ratchet tuning at a constant speed.
Figure 5.4: Free descriptions of the sounds in XP 2.2.2, for the sounds corresponding to a ratchet turning at an varying speed.
Figure 5.5: Free descriptions of the actions and objects causing the sounds in XP 2.2.2 for the sounds corresponding to a racket turning at a constant speed.
Figure 5.6: Free descriptions of the actions and objects causing the sounds in XP 2.2.2 for the sounds corresponding to a ratchet turning at an varying speed.

<table>
<thead>
<tr>
<th>Sujet 1</th>
<th>Preset B</th>
<th>Action</th>
<th>Preset G</th>
<th>Action</th>
<th>Preset 1</th>
<th>Action</th>
<th>Preset 2</th>
<th>Action</th>
<th>Preset 3</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>baguette en bois sur un recipient en metal</td>
<td>frapper d'un objet sur l'auteur avec la main</td>
<td>baguette en bois avec outil en plastique</td>
<td>frapper d'un objet sur une surface en metal</td>
<td></td>
<td>baguette metalique sur une surface metalique</td>
<td>frapper repetee</td>
<td>une bille en plastique et une surface en metal</td>
<td>choc des deux materiaux avec variation de la vitesse</td>
<td>une bille en plastique et une surface en metal</td>
<td></td>
</tr>
<tr>
<td>Sujet 2</td>
<td>Une bille metalique et une assiette</td>
<td>Une table metalique et une assiette</td>
<td>Une bille metalique et une assiette</td>
<td>Une bille metalique et une assiette</td>
<td>Une bille metalique et une assiette</td>
<td>Une bille metalique et une assiette</td>
<td>Une bille en plastique et une surface en metal</td>
<td>Une bille en plastique et une surface en metal</td>
<td>Une bille en plastique et une surface en metal</td>
<td></td>
</tr>
<tr>
<td>Sujet 3</td>
<td>Un verre et une bille ou un verre et une bille</td>
<td>Un verre et une bille ou un verre et une bille</td>
<td>Un verre et une bille ou un verre et une bille</td>
<td>Un verre et une bille ou un verre et une bille</td>
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<td>Un verre et une bille ou un verre et une bille</td>
<td>Un verre et une bille ou un verre et une bille</td>
<td></td>
</tr>
<tr>
<td>Sujet 4</td>
<td>Un outil en bois et un support en metal</td>
<td>une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
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<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td></td>
</tr>
<tr>
<td>Sujet 5</td>
<td>Un outil en bois et un support en metal</td>
<td>une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
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<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td></td>
</tr>
<tr>
<td>Sujet 6</td>
<td>un outil en bois et un support en metal</td>
<td>une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
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<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td>Une bille tombe puis rebondit sur une surface en verre</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.7: Free descriptions of the actions and objects causing the sounds in XP 2.2.2 for the sounds corresponding to a ratchet turning at an varying speed.
<table>
<thead>
<tr>
<th>Sujet</th>
<th>Preset 2</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sujet 1</td>
<td>j'imagine une hélice qui tourne de moins en moins vite et qui cogne sur une plaque de métal</td>
<td>la vitesse à laquelle on appuie et celle à laquelle on relâche décrit la vitesse de la sequence de clics au moment du relâchemet</td>
</tr>
<tr>
<td>Sujet 2</td>
<td>coupe ongle</td>
<td>couper un ongle</td>
</tr>
<tr>
<td>Sujet 3</td>
<td>briquet</td>
<td>cliquer</td>
</tr>
<tr>
<td>Sujet 4</td>
<td>des portes de placard en plastique</td>
<td>quelque chose qui frotte contre une autre chose</td>
</tr>
<tr>
<td>Sujet 5</td>
<td>dispositif mécanique à l'intérieur du &quot;champignon&quot;</td>
<td>faire tomber une bille</td>
</tr>
<tr>
<td>Sujet 6</td>
<td>un objet contenant une bille</td>
<td>secouer</td>
</tr>
<tr>
<td>Sujet 7</td>
<td>billes en vert</td>
<td>choc</td>
</tr>
<tr>
<td>Sujet 8</td>
<td>petit marteau métallique</td>
<td>taper</td>
</tr>
<tr>
<td>Sujet 9</td>
<td>bille</td>
<td>Percussion avec un objet métallique</td>
</tr>
<tr>
<td>Sujet 10</td>
<td>l'objet appui sur quelques choses de métaux comme des petites boules q</td>
<td>c'est un rouleau qui fait office de levier quand on appuie la partie du haut de superieure de l'objet</td>
</tr>
<tr>
<td>Sujet 11</td>
<td>mouvement</td>
<td>cliquetis repetes</td>
</tr>
<tr>
<td>Sujet 12</td>
<td>bille</td>
<td>bondir</td>
</tr>
<tr>
<td>Sujet 13</td>
<td>bille de ping pong</td>
<td>rebondissement</td>
</tr>
<tr>
<td>Sujet 14</td>
<td>capuchon sur un tube - indice de pression + indice de vitesse &gt;&gt; son</td>
<td>pousser, lacher et/ou relever (à une main ou deux mains)</td>
</tr>
<tr>
<td>Sujet 15</td>
<td>gicle métallique sous la pluie</td>
<td>ruissellement de gouttes sur un materiau dur</td>
</tr>
<tr>
<td>Sujet 16</td>
<td>un ressort métallique qui frappe sur un tube métallique également</td>
<td>le fait de pousser le cylindre vers la base</td>
</tr>
<tr>
<td>Sujet 17</td>
<td>stylo bille (Plastique) sur bois</td>
<td>taper</td>
</tr>
<tr>
<td>Sujet 18</td>
<td>verre objet métallique(fourchette)</td>
<td>taper</td>
</tr>
<tr>
<td>Sujet 19</td>
<td>impression d'une percussion d'une tige métallique contre un objet en verre</td>
<td>percussion de moyenne intensité d'un objet sur un autre</td>
</tr>
<tr>
<td>Sujet 20</td>
<td>clic produit par une la melle en métal</td>
<td>pression de la main sur l'objet</td>
</tr>
<tr>
<td>Sujet 21</td>
<td>tambour</td>
<td>presser sur le tambour</td>
</tr>
<tr>
<td>Sujet 22</td>
<td>métal</td>
<td>cliquement</td>
</tr>
</tbody>
</table>