Interaction Design with Audio: Speculating on Sound in Future Design Education

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ABSTRACT
A challenge for future design education in our post-screen world is how to develop design methods, practices, and education for non-visual interaction with interactive systems. The design education approach reported in this paper combines aspects of Sonic Interaction Design, Interaction Design, and physical computing to allow designers to explore the potential role of sound in interaction, and to sensitize designers to the use of sound for interaction. The Interaction Design with Audio (IDwA) approach reported in this paper foregrounds design thinking about the possible design connections between human physical action and sonic responses by interactive systems.

This paper reports on the method and representative case studies of design and learning outcomes from IDwA workshops over three years with undergraduate and postgraduate design students. These case studies indicate that the focus on exploratory design thinking with a novel design task lends itself to sensitising designers to the rich possibilities of using sound in interaction. Exemplar design features include anthropomorphism, functional interaction, narrative flow, and environmental immersion. The case studies of using IDwA illustrate that new and intriguing forms of interaction can be mocked up using simple sensors, physical computing, and a little verve.

Author Keywords
Sound, Audio, Interaction Design, Design Education, Interactive Sound, Design workshop.

INTRODUCTION
We live in a post-screen world of interactive systems where our kitchen appliances talk to us and our shoes vibrate when it is time to go for a walk. Physical design practices such as industrial design and product design have long embraced the multisensory aspects of design (Jordan, 2000). However, approaches to designing and evaluating interactive systems such as Interaction Design (Sharp et al., 2015) have favoured the visual sense (Franinović, 2013). An opportunity exists to develop design methods, practices, and education for non-visual interaction with interactive systems.

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Sound is a complex, expressive, and emotive medium, which unlike visual stimuli can attract our attention even when we are not attending to it, and furthermore, is a medium with which we have the ability to process multiple events at the same time. Much of the research into the role of sound in interactive system design has focussed on the *functional* use of sound to provide: i) notification of system events and actions (Blattner et al., 1989) such as notification of errors or new message arrival; ii) accessible solutions for visually impaired users (Dix et al., 2003); iii) and sonification of data (Hermann et al., 2011). The third wave of Human Computer Interaction (Bødker, 2006), with its focus on the design of interactive *experiences* is a ripe area for deploying sound beyond functional concerns. The field of Sonic Interaction design has championed the foregrounding of sound in Interaction Design, aiming to develop design and evaluation methodologies for "interactive products with a salient sonic behaviour" (Serafin et al., 2011). A challenge for future design education is how to sensitize designers to the use of sound for interaction.

INTERACTION DESIGN WITH AUDIO
Our approach to design education for Interaction Design with Audio (IDwA) combines aspects of Sonic Interaction Design, Interaction Design, and physical computing to allow designers to explore the potential role of sound in interaction as follows:

1. Foregrounding the role of sound in design (Sonic Interaction Design);
2. Prioritising experience over functionality (Interaction Design);
3. Using simple sensors and micro computing platforms to encourage exploration of interaction (physical computing).

Physical computing (O'Sullivand & Igoe, 2004) concerns the connection between the physical world and computers, and physical computing platforms such as Arduino (Banzi, 2009) provide environments with which students can explore non-screen physical interaction such as squeezes, presses, and the physical movement of objects. IDwA uses physical computing with SID design pedagogical approaches (Rocchesso et al., 2013) to facilitate the construction of simple interactive sound systems by designers. In this way IDwA foregrounds design thinking about the possible connections between human physical action and sonic responses by interactive systems. As Serafin et al. (2011) argue, "auditory perception and action are naturally and tightly coupled" – IDwA seeks to support designers exploring this connection in interactive and responsive ways.

IDWA METHOD

Interaction Design with Audio is a hands-on one day workshop in which participants work in small groups to create interactive sound with *found objects*. The groups take an everyday object that does not usually make sound and are instructed to imagine what kinds of sounds it could make when it is interacted with. For example, a watering can that tells stories about plants, or a cup that sings songs about owls when you drink from it at night time. They then use physical computing and audio tools to realize their designs. The workshop is divided into four parts outlined below.

Part 1: Designing the Interaction

Participants are instructed to spend around one hour finding everyday objects in their environment which do not usually make sound. They then take these found objects and imagine what sounds they might make when they are interacted with.

Participants then spend around two hours creating scenarios of use expressed through storyboards (e.g. figure 1), and imagine the sounds that the object would make when interacted with by people or the environment. Emphasis is placed on thinking about the form of physical interaction with the object, i.e. whether it is touched, shaken, squeezed, pressed, stroked, moved, tilted, etc. (e.g. see figure 2 which illustrates participants' thinking about physical interaction with a plant and a chair) and what sort of sound this might elicit from the object. In this way participants explore the physical affordances of objects (cf. Gibson, 1979), and imagine and design possible perceived affordances (cf. Norman, 1988).

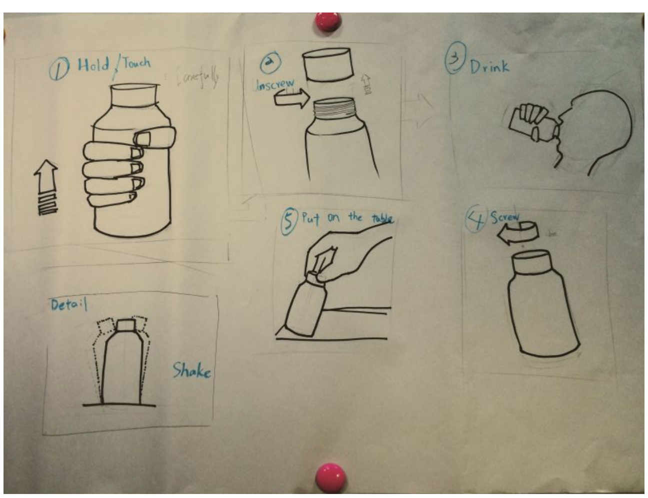

Figure 1: Storyboarding the Interaction

Figure 2: Exploring Forms of Physical Interaction with Objects

The emphasis in this part is placed on **conceptualising how the object *responds* to interaction and its environment**, not on how the object looks.

The results of this first part are presented to the workshop in a show and tell. Importantly, to convey the concept behind their designs, the participants must act out the interactions with the objects and convey a sense of the sounds involved. Figure 3 illustrates one group's presentation of their idea for creating a roller coaster ride for peas from a flexible tube found in the local area. The storyboard is shown to the left of the figure, and the found object (flexible tube) to the right of the figure. In the storyboard the participants have illustrated the kinds of the sounds that the peas would make as they travel through the roller coaster: "Waahooo", "Ahhhhhhh", "Awww, Awww", and also vocalise these sounds for the workshop.

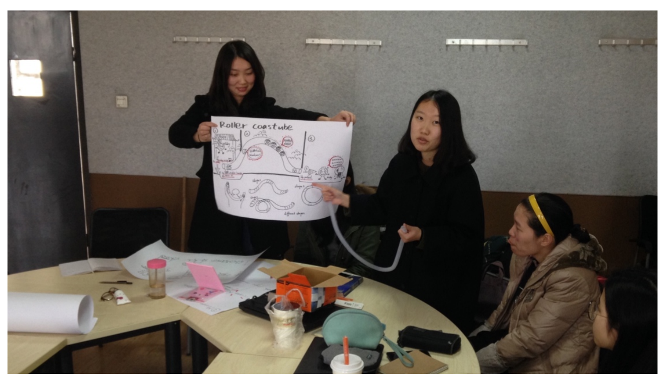

Figure 3: Show and Tell Presentation

Part 2: Creating the Sound

The second part introduces basic audio production techniques for Recording, Producing, Manipulating, and Editing sounds in one hour so that participants can source or record their own sounds for their object. Figure 4 shows the digital audio workflow participants' learn which includes discussion of audio capture, digitising, storage, editing, and sound output. This is a commonplace audio workflow and so open source audio editing tools are used to provide an audio editing suite.

The emphasis in this part is on learning the basics of audio editing and production so that they can be used as a **tool for design realisation** in later parts, much as a graphic designer would learn to use software for graphic editing.

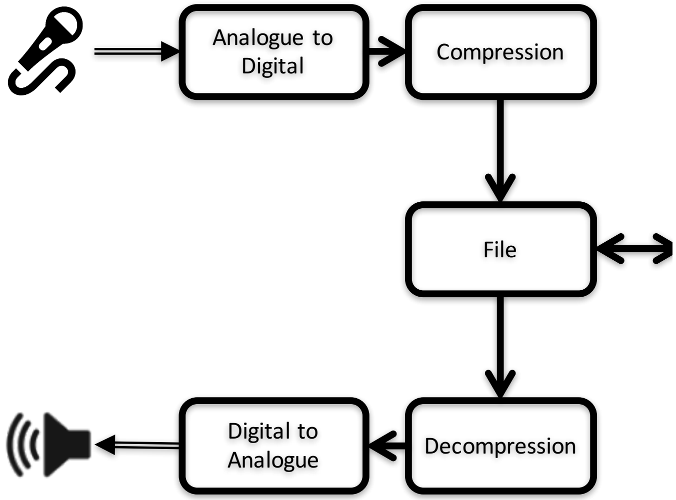

Figure 4: Digital Audio Workflow

Part 3: Making the Sound Interactive

Participants are introduced to physical computing by focussing on using sensors to trigger playback of recorded sounds. Participants learn about different kinds of sensors, their physical characteristics, and how they are processed by computers. Again, the aim in this part is to provide participants with the ***tools* to make their objects** come to life. After one hour of instruction in physical computing participants create their interactive objects using the IDwA platform and sounds they sourced or recorded in the environment.

IDwA Platform

In the IDwA workshops participants use the IDwA platform which is built using Arduino microcomputers[1] along with Adafruit audio boards[2].The first version of the IDwA platform used TinkerKit boards (now defunct) to interface with plug-and-play sensors, whereas the second version used custom printed circuit boards to significantly reduce the physical size of the platform. Reducing the physical size of the platform is an important consideration for the IDwA workshop as the smaller the physical computing boards are, the greater the focus on the object itself rather than the technology.

The IDwA platform is designed to provide a **self-contained physical computing** system which can be powered by batteries and does not need a connection to a computer to function. This is an important element of the design of the workshop – the interactive objects produced are not tethered to conventional computers and are free to be explored in naturalistic ways.

Figure 5a shows IDwA platform version one with the Arduino, WaveShield, and Tinkerkit shield in the top middle, and sensors along the bottom. The sensors connect using plug-and-play connectors which do not require any engineering skills. The platform is powered by one 9 volt battery shown bottom left, and the battery powered speaker for sound output is shown in the top left. The set of sensors provided by the IDwA platform include (from left to right in the figure): Light sensor, Press buttons, Magnet sensor, Movement sensor, and also (shown in figure 5b) Sliders and Tilt sensors.

Figure 5b shows version two of the IDwA platform which is significantly reduced in size whilst retaining the same functionality. The platform is shown at the bottom middle of the figure with physical computing and sound production embedded into one custom printed circuit board. The battery powered speaker is shown bottom left, and sensors are shown at the top of the figure.

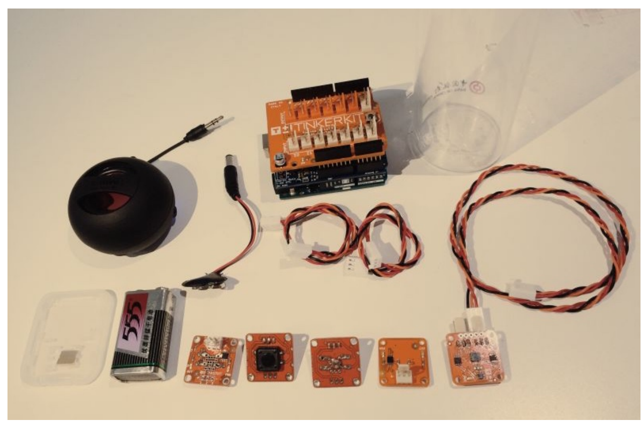

Figure 5a: IDwA Platform Version One

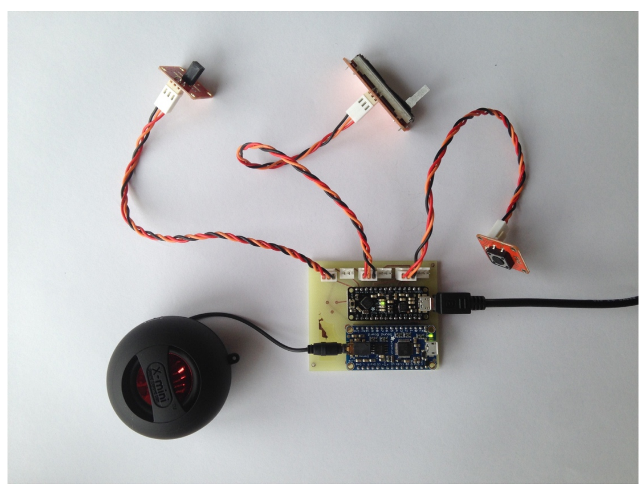

Figure 5b: IDwA Platform Version Two

[1] www.arduino.cc

[2] www.adafruit.com

Figure 6a: Building Interactive Objects with IDwA

Figure 6b: Building Interactive Objects with IDwA

Figure 6 shows participants building their interactive objects using the IDwA platform. Figure 6a shows participants at an early stage of object creation – connecting sensors and using their laptops to manipulate sounds and upload them to the IDwA platform. Figure 6b shows participants towards the end of the creation process when the focus moves to interaction with the object and less on the use of the laptop computer.

It is important to note the pedagogical benefit of using physical computing in these workshops – in both figure 6a and 6b several participants can be seen **working together** on the design and creation. The physicality of the IDwA platform promotes hands-on co-creation between participants, and encourages skill and knowledge sharing through close proximity.

Part 4: Show, Hear, and Tell – Evaluating the Interactive Sound

After spending three hours creating their interactive objects participants present their objects to the workshop by acting out the scenarios of use developed in Part 1. "Show, Hear, and Tell" provokes participants to focus on the auditory aspects of the designs, not solely the visual showing of the object. Importantly in this part, participants are asked to reflect on the role of audio in Interaction Design, focussing particularly on critiquing each others' objects. The focus in this part is on encouraging reflection and critique on how sound can be meaningfully employed in Interaction Design.

CASE STUDIES

The IDwA approach has been studied over three years in five workshops across three locations in urban and rural China, involving 52 undergraduate and postgraduate design students. This section reports on representative case studies of design and learning outcomes of the workshops from the 18 IDwA projects undertaken by students.

Bear

Figure 7 shows an interactive object made from a found soft toy – a bear's head. The bear gets scared at night, laughs when it is stroked, and gets annoyed when its ear is pulled. Interaction is structured as follows:

- The bear is scared of the dark. When it goes dark, the bear makes a scared sound, when it becomes light the bear makes a waking up sound like yawning and stretching. This is achieved using a light sensor over one eye is to determine whether it is night time or day time (in the figure the participants cover the bear's eyes to re-create night time).
- When the bear's head is stroked it makes a happy, contented sound. This is achieved by a slider attached to the back of the bear's head to mock-up the interaction of being stroked. When the slider is moved the bear makes a happy sound to reflect its enjoyment of being stroked.
- The bear doesn't like his ears to be squeezed or pulled – this makes him annoyed. Buttons are attached to the bear's ears so that when his ears are squeezed an annoyed sound is triggered.

Figure 7: Bear

The Interaction Design for the bear is somewhat **anthropomorphic** – participants used the sound and interaction to give the bear **emotional responses** to interactions which tended to be more human than bear. Participants in the group created the sounds for the bear using their own voices and recorded them for editing playback.

It is important to note here that the IDwA platform can be used to convey a **prototypical sense of the interaction** – not necessarily the final, finessed, form of interaction. For instance, stroking the bear's head is detected using a simple slider in conjunction with performing the interaction dramatically. To actually detect a stroking movement may require sophisticated touch sensors and rigorous engineering which is not the focus of the workshop – the focus is on imagining and conveying the forms of interaction.

Bird

In contrast to the bear, another group used a found wooden bird to create an interactive object using **environmental** sounds. Figure 8 shows the wooden bird hanging from the ceiling of the workshop which was held in a rural Chinese village (Wang et al., 2016). The interaction with the bird is structured as follows:

- Like a windchime, the bird makes restful music when the wind blows. This is achieved using a motion sensor on the bird – when a certain level of horizontal motion is detected (i.e. a threshold of acceleration is passed in the x or y plane) restful music is played.
- The bird likes to be interacted with. When touched, the bird sings a bird song to show its enjoyment. This is achieved by triggering bird song samples when a certain level of vertical motion is detection i.e. a threshold of acceleration is passed in the z plane.

The sounds for the bird were gathered from the local environment (the birdsong was recorded and edited in-situ), and from online sources to gather the relaxing music. The use of local materials (the wooden bird) and local sounds (bird song) demonstrates the situatedness that can be achieved with IDwA - participants absorb themselves in the **multi-dimensionality of the world** around them (physical objects, environmental sounds) in addition to the visual elements of the environment. Such an approach could be used to stimulate rich design immersion.

Figure 8: Bird

It is worth noting that whilst there are two forms of interaction (blowing in the wind, and person interacting with the bird), only one 3-dimensional sensor is required. In this way a rich form of design thinking is achieved with a small amount of technological development. In IDwA it is important to **foreground the interaction over the technology**.

Purse

The bear and bird were both animals brought to life through interactive sound, with some elements of anthropomorphism. A contrasting example is the purse illustrated in figure 9. The interaction with the purse is:

- The purse doesn't like its owner to spend money. When opened any money is taken out, the purse will complain that too much money is being spent. This is achieved using a simple switch to detect when the purse is opened, and then triggering playback of a recording of a human voice.
- The purse likes to be taken when the owner leaves the house. When the purse is picked up it says how happy it is and how much it enjoys being picked up by its owner. This is achieved using a motion sensor to detect a change in position and then trigger playback of a recording of human voice.
- The purse has a love life. When a photograph of a cure person is put into the purse it says how beautiful the person is. This is achieved by attaching a magnet to a

photo of a person, and secreting a magnet sensor in the purse. When the magnet on the photo is detected in the purse a recorded sample is played back.

The purse is interesting as it shows anthropomorphism of an inanimate object – bird and bear made some sounds that were somehow similar to what a real bird or bear might make. Furthermore, as the purse is an everyday object it illustrates how IDwA could be used to **facilitate design of future interaction**. For example, whilst there are currently Internet of Things sensors which can be used to detect if you left the house without your purse (i.e. similar to the purse interaction where it makes a happy sound when you pick it up), there are no existing systems which respond to photographs being put into a wallet, or physical money being taken out of a wallet. These two forms of interaction may be interesting avenues for future product design exploration.

Figure 9: Purse

Bottle

The bottle shown in figure 10 exaggerates reality. Unlike the bear, bird, and purse objects, bottle does not present any emotional states, but instead exaggerates typical sounds of people using the bottle in a comedic way. The interaction with the bottle is:

- When the top is opened the bottle makes a loud hissing noise. This is achieved by attaching a button to the top of the bottle – when this is pressed (as the bottle is opened), the sound of hissing fizzy drink is triggered.
- As the bottle is tilted up it makes a gurgling/ slurping/ drinking sound. This is achieved using an accelerometer to detect when the bottle is not vertical, and then triggering the gurgling sound.
- When the bottle is placed back on the table it emits a burp. This is achieved using a light sensor attached to the base of the bottle – when the bottle is placed on the table the sensor is darkened and the sound of a burp is triggered.

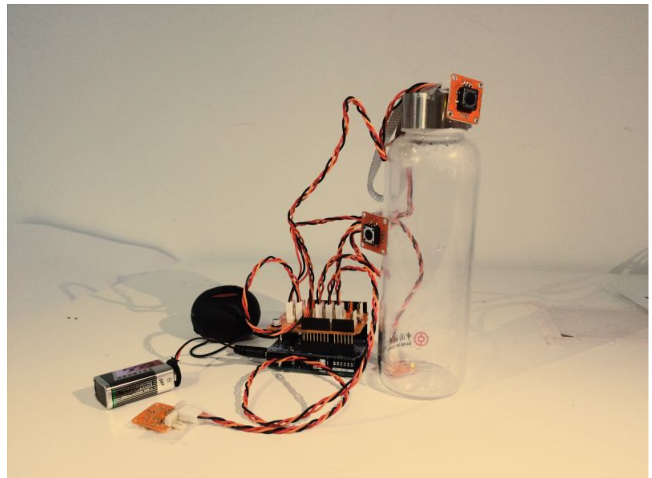

Figure 10: Bottle

The bottle shows how sounds could be used for comedic effect simply by exaggerating everyday sounds. This might have application in toys or novelty items. The bottle also shows, again, how different **forms of interaction can be mocked up with simple sensors and some dramatic verve** – the sound of opening of the bottle is triggered by a simple button rather than a complex twist sensor.

Dong Tunes

Figure 11 shows Dong Tunes (Wu et al, 2017), an interactive object which plays recordings of spoken stories when the extremities of the object are turned as illustrated in the figure where the person is twisting the bottom-most extremity. The recordings are of stories spoken by Chinese local villagers (Kam) during a cross-cultural design field trip (ibid). Unlike the bear, bird, bottle, and purse, Dong Tunes demonstrates a functional yet **indirect interaction mapping** – the sounds that are triggered are not related to the action that triggered them i.e. the turning of the extremity does not produce some sort of turning sound or sound that might result from turning as in the opening of the bottle. As such, the interaction is more functional than other case studies here, whilst retaining the non-screen interaction ethos of IDwA. Dong Tunes used twist sensors to detect turning of each of the extremities and then triggering the playback of the recorded story.

Interestingly, as reported in (Wu et al, 2017), when Dong Tunes was shown to people with no understanding of Chinese they found the spoken words more interesting than a version which played local music. This indicates how sound can be used in cross-cultural design even when the content is incomprehensible to an audience.

Figure 11: Dong Tunes

Lemon and Sausage

Interactive sound objects can also be used to support dramatic performance as illustrated by the lemon and sausage objects created by one group and shown in figure 12. In this case study the group developed a narrative about a lemon and a sausage who fell in love when young, then drifted apart in young adulthood, finally serendipitously reuniting in old age and rekindling their love for each other. This story was then acted out by the group using the lemon and sausage as the main characters, with spoken narration, and triggering recordings of the characters' lines at each step of the narrative. As with Dong Tunes, this is a form of indirect interaction mapping – the triggering of the recordings does not directly relate to the physical affordances of the interaction with the object, but instead this time supports plot steps in a **narrative**.

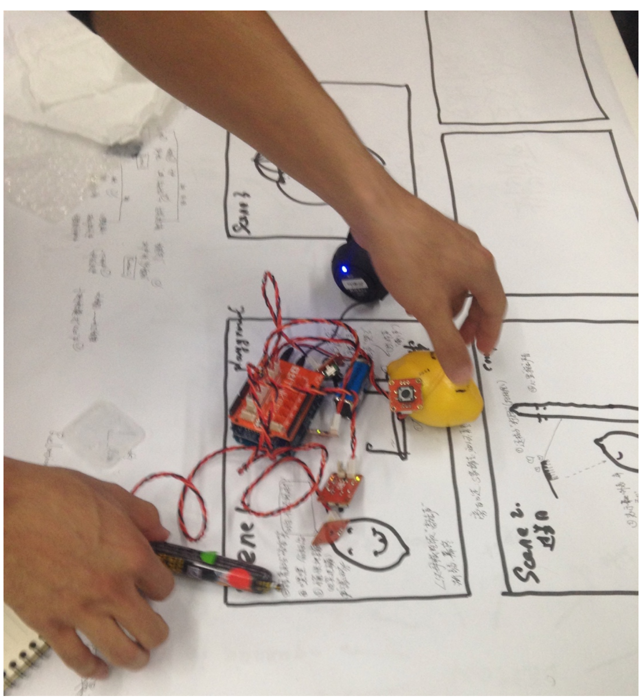

Figure: 12: Lemon and Sausage

The sounds in this case study were triggered using buttons to move through a sequence of recorded spoken words for each line of the narrative. In this way the lemon and the sausage are both props for the narrative, and also sources of narrative content. This use of IDwA could be exploited in performance or to help convey rich scenarios of interaction or collaboration by adding a sonic element to scripted narratives.

Summary of Interactions and Sensors

The presented case studies illustrate a range of interaction triggers and associated sensors. These are summarised in table 1 which shows that within a short period of time participants were able to develop a number of input gestures (e.g. stroking, opening, picking up), sense the environment around them, and use a range of physical computing sensors to trigger sounds. It is also worth noting that in IDwA workshops participants find multiple ways to use the same sensors in their designs e.g. in these case studies accelerometers were used to sense: pulling, movement in the wind, picking up, and tilting.

Object interaction	Environmental change	Object	Sensor
Stroke		Bear	Slider
Press		Bear	Button
	Light	Bear	Light sensor
Pull		Bird	Accelerometer
	Wind	Bird	Accelerometer
Open		Purse	Button
Pick up		Purse	Accelerometer
	Introduce object	Purse	Magnet sensor
Twist open		Bottle	Button
Tilt		Bottle	Accelerometer
Put down		Bottle	Light sensor
Twist		Dong Tunes	Twist
	Narrative change	Lemon and Sausage	Button

Table 1: Summary of Interactions and Sensors

SUMMARY

IDwA is a methodology which encourage participants to think about sound in interaction. The case studies indicate that the focus on exploratory design thinking with a novel design task (making an inanimate object produce sounds) lends itself to sensitising designers to the rich possibilities of using sound in interaction. Some of the case studies are absurd (a lemon and a sausage falling in love), some of the designs are anthropomorphic (a teddy bear that is scared of the dark), and some of the designs are comedic (the burping bottle), and yet all the designs demonstrate how sound can be used to in fun, functional, engaging, enticing, intriguing, and responsive interactions.

By encouraging designers to explore and improvise interaction outside their training and experience they become **sensitized to potential new forms of design practice**. This in turn may uncover new and previously unimagined design directions. The purse is a exemplar case of how thinking about what the purse would say when objects are put into it and removed from it highlights possible future design directions for connected purses. Similarly, encouraging participants to explore the sonic environment around them encourages them to think about the world as a multi dimensional interaction space, much as they would in a sound walk. For example, in creating the bird the participants spent time exploring their rural environment to record sounds of birds which became part of their Interaction Design. Furthermore, the range of sounds captured and used in the case studies illustrates how IDwA can be used to expose designers to how sonic interaction can be prototyped using human voice, spoken word, found sounds, environmental sounds, foley sounds, and pre-recorded audio.

The short duration of the IDwA workshop combined with the emphasis on speculative and playful design responses makes it more suitable for design exploration and sensitization to sonic design practices, rather than concrete design development. This can be seen in the case studies reported in this paper which may be starting points for possible future design requirements and product design e.g. the bear could be inspiration for future interactive toy development.

Design Trade-offs

Sound is a temporal medium and so one of the key design trade-offs in interactive sound design is the length of sound that is produced in response to triggers versus the interactivity of the system. Dong Tunes and lemon and sausage both used long recordings of spoken word in their interaction (sometimes over ten seconds). In doing so the form of interaction becomes more of an **activate-and-listen** form where participants trigger a recorded sound and then listen until the end. This is in contrast to other case studies such as the bottle which makes short sounds (up to a second or two) in response to movement. In the bottle the movement action becomes **viscerally connected** to the sound produced, and a tight action-response loop is created between someone's actions and the response of the bottle. An important element of the Show, Hear, and Tell part is encouraging participants to reflect on these different interactive forms and discuss their applicability to different design scenarios.

There is a strong connection between the form of the interaction (activate-and-listen vs. visceral connection) and the interaction mapping. As illustrated in the case studies, activate-and-listen forms of interaction use **indirect mapping** of gesture to sound – the gestural action that activates the sound is not related to the sound that is produced. In contract, visceral connections usually have a **direct mapping** between gesture and sound e.g. a twist of the bottle cap produces an exaggerated sound of opening a bottle. This is in part due to the necessarily short nature of gestures such as pressing or turning, and is in part a conscious design choice of the participants. For example, in Dong Tunes, the spoken word recordings could be triggered by continually turning the interactive elements to continue playing the sounds, but this would become physically tiring quite quickly.

Design Responses

IDwA sets its participants an open-ended design objective of imagining an inanimate object's auditory responses to interaction. The workshop does not specify what form the conceptual design should take beyond the requirement of using sound as the primary form of response. The case studies reported here illustrated the kinds of conceptual design seen across all IDwA workshops to date.

The most frequent forms of interaction created in the workshops are **anthropomorphic** and **emotive**. Giving inanimate objects a "voice" is both popular and intuitive for participants, whether it is spoken word responses or some sort of emotional non-verbal sound. This is often combined with some form of exaggerated physicality of interaction such as the bottle responds with exaggerated sounds when interacted with. This typically produces a humorous experience which plays on expectations and comedic timing. Anthropomorphism and humour provide space for designers to think about emotional design interaction from the perspective of the object, and how this would relate to the emotion and action of the person.

Participants also respond with more **functional** responses such as Dong Tunes in which the content of the audio is foregrounded over the interaction itself, and, more **narrative** responses such as lemon and sausage in which the objects act as props supporting a scripted plot. In terms of Interaction Design these design approaches provide insight into the content and flow of possible designs, and ask designers to consider what would be salient content.

Finally, a small number of objects used recorded sounds from the surrounding **environment** to somehow capture a moment in time and space. For example, the bird played recorded sounds of local birds in a rural location that may be visited only once. These designs explore the quality of the world around us, and what elements of the essence of experience can be capture and interacted with.

It is interesting to note that no groups created musical instruments with the IDwA platform. This may either be because they were instructed to try to give voice to found objects, or it may be due to the limited number of samples that could be triggered by the IDwA platform, or even may be due to the musical experience (or lack of it) of participants.

Learning Outcomes

Through the case studies in this paper we have suggested how the IDwA workshop can facilitate designers learning about the properties of sound, how to record and edit it, and how to use sound in interaction. We have shown how participants use sound to drive exploration of conceptual design which may produce novel and surprising results, and which we believe can help to sensitize designers to the potentially rich use of sound in Interaction Design. The case studies also illustrate how physical computing platforms can be readily used by participants with little computing experience, and how physical computing facilitates hands-on group work and shared learning through physical proximity. Finally, we believe that our case studies of using IDwA show that new and intriguing forms of interaction can be mocked up using simple sensors and a little verve.

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