UNIVERSITY OF TWENTE

MASTER OF SCIENCE

MARKETING COMMUNICATION

How long does it take to fill up a one-liter jar?

Effects of Sound and Vision on Perception of Running Water

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Abstract

People form their judgments of everyday phenomena based on multisensory information. This study investigates the relative impact of visual and auditory information on the perception of running tap water. Two visual and two auditory stimuli were combined to create four different combinations of high and low volumetric flow rate of tap water (the volume of water which passes through a faucet per time unit). Participants in each condition were asked to judge how long it would take to fill up a one-liter water jar. The results demonstrate that the evaluation of the volumetric flow rate of tap water was significantly influenced by both visual and auditory information. These results suggest that auditory information can play a significant role in everyday experience of running tap water even though participants are normally unaware of the effect of audition. These findings can be used to design environmentally friendly water faucets for public bathrooms, and thus to reduce the everyday water consumption.

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1 Introduction

1.1 Need in Water Consumption Reduction

Significant public attention has been paid to the issue of water scarcity lately, and for good reason. Although water is a renewable resource, it is also a finite one. Only 2.53 percent of earth's water is fresh, and some two thirds of that is locked up in glaciers and permanent snow cover (www.water.org statistics, 2012).

Doubtlessly, water is one of our most precious and valuable resources. Despite its importance, over one billion people around the globe still lack access to clean water and thousands perish daily for lack of it. In the natural world, many of our most important aquifers are being over-pumped and half of the world's wetlands have been lost to development. The world's water problems flow from failure to meet basic human needs and inability to balance human needs with the needs of the natural world. These maladies are both rooted in a wasteful use of water and an antiquated mindset towards gathering and distributing it (Gleick, 2011).

Global climate change will pose a wide series of challenges for freshwater management as a result of changes in water quantity, quality, etc. Sustainable management of shared water resources in a changing climate will be especially challenging (Cooley et al., 2009).

There are different ways to tackle environmental problems, such as waste management and rehabilitation, developing new technologies, improving current uses of natural resources (Maczulak, 2010). This paper suggests an alternative way to reduce human water consumption through the manipulation of auditory information. Namely, it is demonstrated how the sound of "noisy" faucets can influence human perception and judgment. In their research on product noisiness, Fenko, Schifferstein, & Hekkert (2011) concluded that the noisiness of electric kettles and alarm clocks contributed to the affective reactions, annoyance and unpleasantness, in product experience. In this research, a product's (faucet) noisiness is manipulated to investigate human perceptual reactions. Participants will watch the video of tap water running and because the faucet will produce more noise, it is expected that they will evaluate more water running and will hurry up to stop the video (i.e. to close the tap); and vice versa – less noisy faucet will make participants evaluate less water running and they will take more time to stop the video (i.e. to close the tap). Further, it is also proposed how the findings of this research might serve as the first conceptual step in the development of "smart noisy faucets".

1.2 Nonconscious Influence on Cognition and Behavior

Environmental attitudes and intentions are known to influence environmentally responsible behavior (Bamberg & Möser 2007; Kaiser, Wölfing, & Fuhrer 1999). Examples of the theories of behavior change are stages of change theory, elaboration likelihood model, and theory of planned behavior (Witte, Meyer, & Martell, 2001). These theories share major components like intentionality and a period of time needed for behavior change to occur. In other words, individual must engage in a conscious pursuit of goals over a period of time.

Nonconscious influence on cognition and behavior, on the other hand, does not require intentionality and a period of time, i.e. the process takes place without one's awareness and normally immediately upon activation. It is mainly acknowledged that lower levels of processing, such as motor reflexes and sensory analysis do not require perceptual awareness (Kouider & Dehaene, 2007). For example, Holland, Hendriks, & Aarts (2005) found in a series of studies that by introducing an olfactory cue (citrus scent), it is possible to influence the cognition and behavior of people – participants thought of cleaning more and engaged in a more "clean" behavior during eating. Importantly, it was found that participants were unaware of the influence of the scent on their cognition and behavior. According to Holland et al. (2005), the change in cognition and behavior was possible because "a strong semantic association between a typical cleaner scent and cleaning behavior was established" (p. 690). As mentioned above, sensory analysis does not require perceptual analysis. In the next section, different examples of sensory analysis are discussed within the framework of multisensory integration. It is also suggested how multisensory integration can be used to promote environmentally friendly behavior.

1.3 Multisensory Integration

Many of daily sensory experiences happen without one's awareness through the process of multisensory integration. Multisensory integration refers to the process by which a brain combines information from different senses and formes a coherent experience (Wallace, 2004). Wallace fairly pointed out that "one of the most ubiquitous features of nervous systesms, from the simplest to the most complex, is an ability to combine and synthesize information from the different senses" (Wallace, 2004, p. 69).

Humans “explore their environment using a variety of modalities and internal representations of the sensory world are formed by integrating information from different sources. The information arriving through different sensory pathways may be complementary. For object identification, for example, auditory information, such as the moo of a cow, may help to identify the visual entity, the shape of the cow” (Newell, 2004, p. 123).

However, the process of multisensory integration does not always occur in a “right way”. The best example is a known phenomenon called synesthesia. “Synesthesia (Greek, syn = together + aisthesis = perception) is the involuntary physical experience of a crossmodal association. That is, the stimulation of one sense causes a perception in one or more different senses” (Cytowic, 1995, p. 1). For instance, a synesthete can perceive (see) a letter and experience a color at the same time. Another synesthete described the cry of her baby as an unpleasant yellow color. Synesthesia is uncommon and shared by only a small portion of the population (Grossenbacher & Lovelace, 2001).

Whereas synesthesia is a rare phenomenon, other perceptual processes are experienced by a majority of individuals and are quite common. Typically, humans are not aware of the crossmodal (cross-sensory) interactions taking place and therefore, allow scientists to induce perceptual changes in one sensory modality by manipulating the other. Scientific evidence suggests that it is possible to manipulate one sense and alter the experience in another (or other) modality (s) without subjects being aware of the process taking place. One example is a well-known rubber hand illusion. The illusion is formed through the following process: one watches a rubber hand being stroked with a brush, while being simultaneously stimulated in the same way but one's real hand. As a result, one quickly incorporates the rubber hand into their body image. Even when subjects know of the mechanism taking place, the illusion still persists (Hagni et al., 2008).

Other illustrative examples of perceptual illusions are ventriloquism, McGurk effect, and sound-induced flash illusion. Ventriloquism refers to "the perception of speech sounds as coming from the same direction as the visually observed speaker even though they are not actually coming from the same direction" (Jack & Thurlow, 1973, p. 967). In other words, audience in a cinema perceives that characters speak on the screen whereas the sound comes from the speakers located at the back of the cinema. Ventriloquist is a showman who manipulates a dummy's (puppet) lips and avoids moving his own lips, which produces a perceptual illusion of the puppet speaking.

McGurk effect was discovered by McGurk and McDonald (1976) and refers to the phenomenon when the auditory element of one sound is combined with the visual element of another sound, which produces a perceptual illusion of a third sound, which is not produced in reality (McGurk & McDonald, 1976).

The last perceptual illusion described here was reported in a series of experimental studies by Shams, Kamitani, and Shimojo (2002) and Shams, Ma, and Beierholm (2005). It is a crossmodal illusion induced by sound: a single flash of light is accompanied with multiple auditory beeps and as a result, participants perceive multiple flashes and are unaware that these multiple flashes are absent in reality.

The above examples of cross-sensory illusions are possible due to spatiotemporal congruity, which is necessary for multisensory integration to take place (Spence, 2011).

In most cases, it is possible to make a scientific guess whether crossmodal interactions will take place given that the factors of spatiotemporal and semantic (example of semantic congruency is the citrus scent experiment mentioned earlier in section 1.2) congruency are present (Spence, 2011).

Crossmodal correspondence has been defined by Spence (2011) as a "compatibility effect between attributes or dimensions of a stimulus (i.e., an object or an event) in different sensory modalities (be they redundant or not). Such correspondences occur between polarized stimulus dimensions, such that a more-or-less extreme stimulus on a given dimension should be compatible with a more-or-less extreme value on the corresponding dimension (s). A key feature of (or assumption underlying) all such crossmodal correspondences is that they are shared by a large number of people and some may, in fact, be universal" (Spence, 2011, p. 973).

For example, Zampini and Spence (2004) modified the sounds produced during the biting action and afffected the perception of the crispness and staleness of potato chips. Also, Zampini and Spence (2005) found that increasing the sound of sparkling water affected the perception of the level of the carbonation of the water. Zampini and Spence (2004; 2005) concluded that these experimental studies highlight the significant role that auditory cues can play in modulating the perception and evaluation of products even though individuals are often unaware of the influence of such auditory cues.

1.4 Audition and Vision

The present research paper focuses on two senses (audition and vision) and explores the influence of auditory information on human perception and judgment. It is expected that a more “noisy” faucet will make participants evaluate more water running even though the visual information is incongruent. Respectively, it is expected that a less “noisy” faucet will make participant evaluate less water running even though the visual information is contradictory. Such a prediction is based on the theory and the empirical evidence from the two lines of research: crossmodal correspondence and sensory dominance. In his tutorial review on the nature of crossmodal correspondences between audition and vision, Spence (2011) outlined three types of correspondences under which the phenomenon is expected to occur: structural, semantically-mediated, and statistical correspondences. The relevant type of crossmodal correspondences for this research is a statistical correspondence, which occurs for stimuli which happen to be correlated in nature (Spence, 2011). For instance, if one sees more water running, s/he expects the water to produce more noise and vice versa.

At early stages of research, it was generally acknowledged that vision is dominant compared to audition. That is, if conflicting information is present, vision will dominate. However, recently, a more balanced view emerged, that of visual dominance in spacial information processing and auditory dominance in temporal one (Guttman, Gilroy, & Blake, 2005). This recent view represents the modality-appropriateness hypothesis (Welsch, DuttonHurt, & Warren, 1986) and explains the earlier-mentioned sound-induced flash illusion.

As mentioned earlier, in everyday situations, information from different senses is synthesized into a coherent perceptual experience through the process of multisensory integration (Wallace, 2004). However, if the information is conflicting (incongruent), the brain needs to solve the perceptual problem. Experimental studies on sensory dominance reported by Fenko (2011) yielded support for the two ways in which the perceptual problem is solved. One way is that an individual will disregard the information from one sense and will use only one sense. The other way is that an individual the information from both senses will be used and will result in some kind of compromise between the two senses (Fenko, Schifferstein, & Hekkert, 2011; Fenko, Otten, & Schifferstein, 2010; Fenko, Schifferestein, Hekkert, 2010; Fenko, Schifferestein, Huang, & Hekkert, 2009).

In line with the afore-mentioned need in alternative ways to reduce water consumption and scientific evidence from the research on multisensory integration, I propose to investigate the influence of auditory manipulation on human perception and evaluation of running tap water. In particular, it will be demonstrated how the sound of a “noisy” faucet influences human judgment on filling up a one-liter jar. Subjects will watch be exposed to the audio-visual stimuli of running tap water and will be asked to pause the audio-video when they think that the one-liter jar is full. It is predicted that subjects will think that there is more water running and hurry to close the tap when exposed to the “noisy” audio stimulus even though the visual stimulus is incongruent. Respectively, the audio of a less “noisy” faucet is expected to make subjects think that there is less water running and take more time to fill up a one-liter jar and close the tap. The present study includes two stages: pre-study and main study.

The objectives of the pre-study were:

1) to demonstrate that participants indeed see the differences between different volumetric flow rates (*the volume of fluid which passes through a given surface*

per unit time measured as “one liter per # of seconds”) of running tap water based on video and audio information;

2) to demonstrate that participants are capable of relatively accurately judging when a one-liter jar is full given that they have a reference point.

The objective of the main study was to demonstrate that the manipulation of auditory information can influence human perception and judgment in both ways: more noisy sound of water running will make participants evaluate more water running and less noisy one will make participant evaluate less water running even though the visual information is incongruent (contradictory).

2 Pre-study

2.1 Methods

2.1.1 Participants

The participants were 45 students and employees of the University of Twente who resided on campus and were recruited from nearby dormitories. Their ages ranged from 20 to 35 years old, and the mean age was 25. There were 12 females and 33 males.

2.1.2 Stimuli and Procedure

The pre-study had two components: demo and the actual pre-study. The materials were videos with audios of tap water. The apparatus used was a laptop with attached headphones. ***Demo.*** The participants were exposed to the audio-visual stimuli of a person (only hand is visible in the video) filling up a one-liter jar (Illustration 1). The volumetric flow rate of water was 1 liter per 16 seconds (i.e. it took 16 seconds for 1 liter to fill up).

The purpose of the demo was to give participants a reference point for the actual pre-study. ***Pre-study.*** Participants were exposed to three versions (Illustrations 2,3,4) of the audio-visual stimulus of water running from the same faucet as in the demo but *without the one-liter jar*. The stimuli were different by the time it took for a liter to fill up: 8 seconds, 16 seconds, and 24 seconds. The participants were asked to imagine that they are filling up the one-liter jar from the demo and to pause the video/audio when they thought it was full. The measure was the number of seconds on the moment of pause.

Illustration 1: Demo video/audio

Illustration 2: liter per 8 seconds

Illustration 3: liter per 16 seconds

Illustration 4: liter per 24 seconds

2.1.3 Results

The results showed that the objectives of the pre-study were achieved. In particular, participants were capable of seeing the differences among the three different volumetric flow rates and were capable of relatively accurately judging when the one-liter jar was full. The mean (liter per seconds) for the video of 8 seconds was 9.73, for the video of 16 seconds was 18.18, and for the video of 24 seconds was 25.22 (Figure 1).

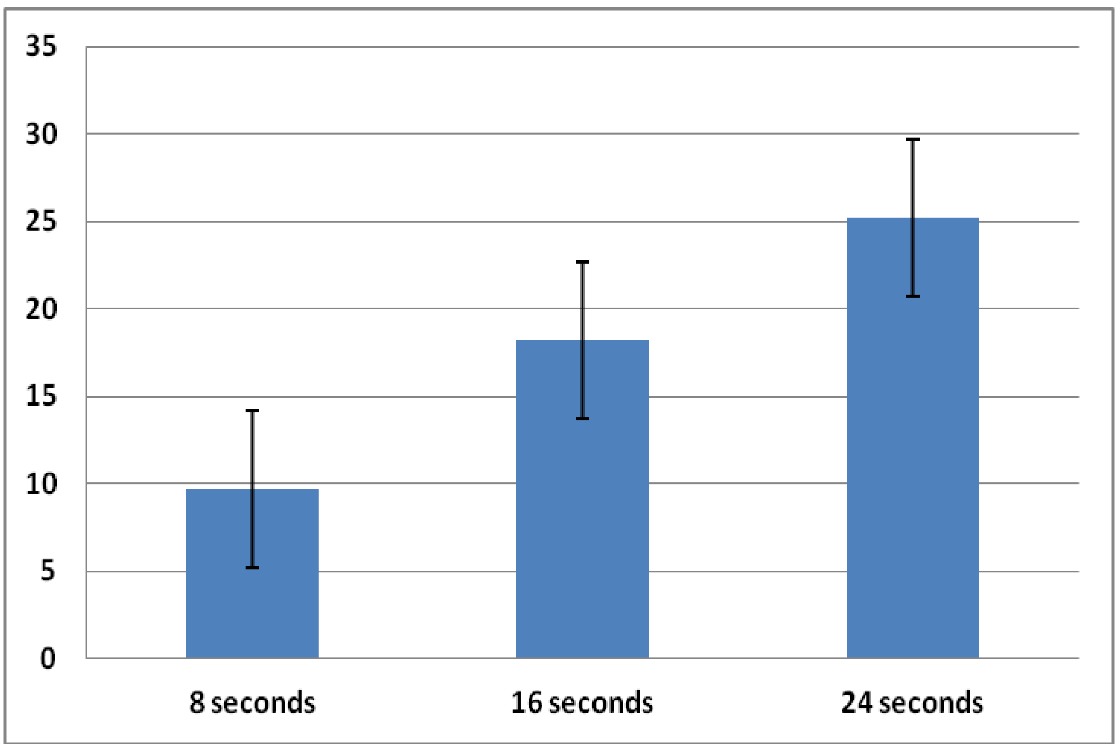

Figure 1: Reported Evaluations of Different Volumetric Flow Rates

3 Main Study

3.1 Methods

3.1.1 Particpants

160 University of Twente students and employees were recruited in the coffee-break corner outside the Vrijhof library. The students participated voluntarily and received a chocolate or a granola bar at the end of the experiment as a thank you gesture. Their ages ranged from 17 to 53 years old with the mean age of 23. There were 80 female participants and 80 male participants. All participants were unaware of the purpose of the experiment which was confirmed during the debriefing. All participants reported good hearing and good, or corrected-to-good, vision.

3.1.2 Materials

As in the pre-study, the materials were videos/audios of tap water. The apparatus used was a laptop with attached headphones (same as in the demo and the pre-study).

3.1.3 Experimental Design

A 2 (video: 24 sec. vs. 8 sec.) x 2 (audio: 24 sec. vs. 8 sec.) between-subjects factorial design was employed. Two audio-visual stimuli were prepared:

Stimuli	**Video**	**Audio**
Fast	Liter/**8 sec.**	Liter/**8 sec.**
Slow	Liter/**24 sec.**	Liter/**24 sec.**

The audio-visual stimulus of 1 liter per 8 seconds was classified as *fast* and the audio-visual stimulus of 1 liter per 24 seconds was classified as *slow*. The manipulation consisted of switching the audio of the two audio-visual stimuli, which resulted in 4 combinations/conditions:

Stimuli	**Audio**	**Video**
Fast	Liter/**8 sec.**	Liter/**8 sec.**
Slow	Liter/**24 sec.**	Liter/**24 sec.**
Fast Audio/Slow Video	Liter/**8 sec.**	Liter/**24 sec.**
Slow Audio/Fast Video	Liter/**24 sec.**	Liter/**8 sec.**

All the participants were first asked to watch the demo (same as in the pre-study) and then randomly assigned to one of the four experimental conditions (fast, slow, fast audio/slow video, or slow audio/fast video) and were asked to imagine the 1-liter jar from the demo and to pause the video/audio when they thought it was full. The volume and resolution were held constant across the four conditions.

3.1.4 Procedure

Participants were approached individually in the coffee-break corner outside the university library and asked to participate in a study for a water conservation project. On the laptop situated on a bar-height round table, participants read the following instructions from the screen:

The aim is to research the perception of running tap water for a water conservation project.

You will watch:

1) *A short video of a person filling up a 1-liter jar with tap water.*
2) *The other short video of running water from the same faucet but this time – without a person and without the 1-liter jar, just running water. Water volume is not necessarily the same as in the first video.*

Please imagine that you are filling the 1-liter jar and pause the video when you think it is full.

First, participants watched the demo video/audio with the one-liter jar becoming full of tap water within 16 seconds (the same demo video as in the pre-study). Further, participants were asked to imagine the one-liter jar from the demo and to pause the video/audio when they thought it was full. After the completion of the experiment, the participants were debriefed, thanked, given a chocolate or a granola bar and dismissed.

3.1.5 Results

A two-way ANOVA was performed on participants' judgment of volumetric flow rates with Vision and Audition as between-subject factors. Both effects were statistically significant at the .01 significance level. The effect of Vision yielded an F ratio of $F(1, 156) = 47.63$, $p < .001$, partial $\eta^2 = .23$. The effect of Audio yielded an F ratio of $F(1, 156) = 16.03$, $p < .001$, partial $\eta^2 = .09$. There was no interaction effect found $F < 1$, *ns*.

The Effect of Auditory Manipulation on the Evaluation of Volumetric Flow Rate. The combination of fast audio and slow video resulted in the evaluation of less seconds required to fill up a one-liter jar (*M* = 18.38, *SD* = 5.61) in comparison with the congruent combination of slow audio and slow video (*M* = 22.45, *SD* = 7.21). Respectively, the combination of slow audio and fast video resulted in the evaluation of more seconds required to fill up a one-liter jar (*M* = 15.43, *SD* = 7.10) in comparison with congruent combination the fast audio and fast video (*M* = 11.35, *SD* = 5.63).

The results for no-manipulation conditions of fast audio/fast video (*M* = 11.35, *SD* = 5.63) and slow audio/slow video (*M* = 22.45, *SD* = 7.21) were comparable with the pre-study results of fast audio/fast video (*M* = 9.73, *SD* = 4.18) and slow audio/slow video (*M* = 25.22, *SD* = 8.5)

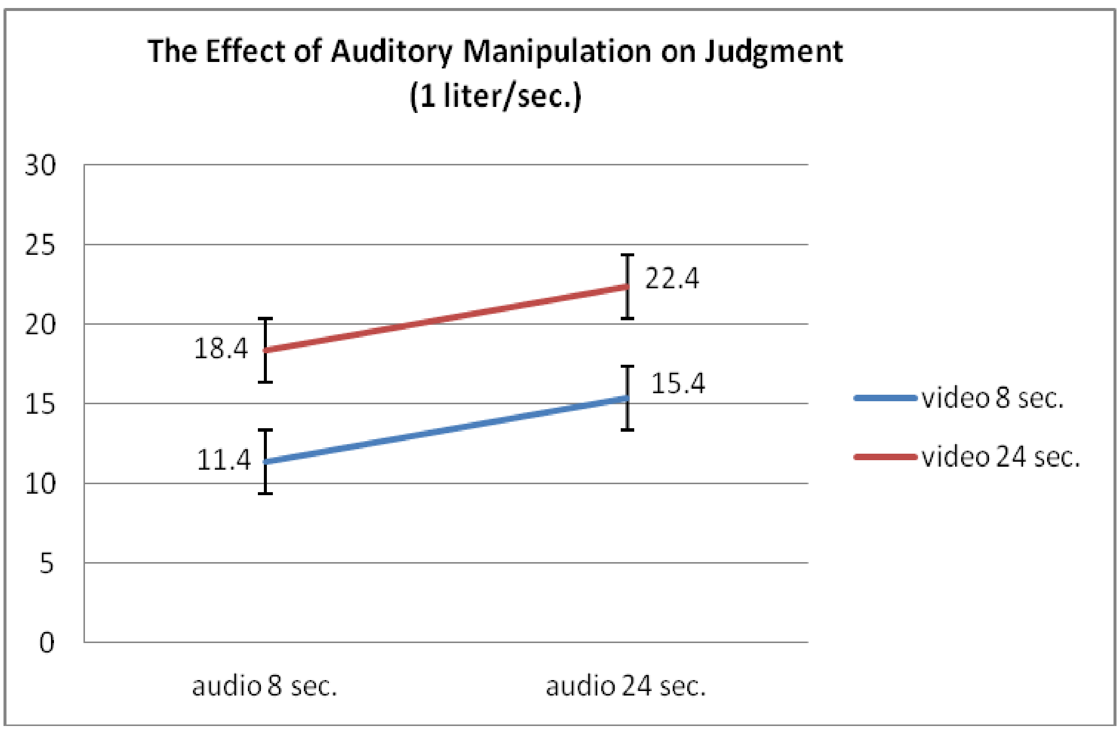

Figure 2: The Effect of Auditory Manipulation on Human Judgment

4 Discussion

The results (Figure 2) show that the vision was more dominant however, the manipulation of the sound of tap water (audition) also significantly affected participants' evaluation of volumetric flow rate of tap water.

The analysis of the data from this experimental study confirms that the manipulation of the auditory information can affect the overall perception and experience of everyday process, such as running tap water. In particular, the results show that the overall evaluation of the volumetric flow rate (volume of water which passes through a faucet per time unit) is influenced by the intensity of the sound of this tap water. The volumetric flow rate was judged as higher when the slow video was combined with the fast audio. Respectively, it was judged as lower when the fast video was combined with the slow audio demonstrating the significant main effects of both audition and vision (with vision being dominant). There was no interaction effect observed, which is in line with the Additive Model of Sensory Integration (Schifferstein & Fenko, 2010). According to this model, the evaluation of a combination of stimuli equals the sum of the (weighted) subjective values of the given stimuli. The model assumes that the subjective value of each stimulus is independent of the other stimuli it is combined with.

The findings support both the phenomenon of statistical crossmodal correspondence outlined by Spence (2011) and the suggested outcomes of the sensory dominance phenomenon confirmed by the experimental studies by Fenko (Fenko, Schifferstein, & Hekkert, 2011; Fenko, Otten, & Schifferstein, 2010; Fenko, Schifferestein, Hekkert, 2010, Fenko, Schifferestein, Huang, & Hekkert, 2009).

The statistical crossmodal correspondence phenomenon occurred, which is demonstrated by the significant differences between the control and the experimental groups. Switching the high volumetric flow rate audio with the low one did have a significant influence on the human evaluation of the volumetric flow rate of running tap water.

As it was mentioned earlier, if the information coming from two different senses is conflicting, then there are two possible outcomes: either one of the senses will be ignored or the information will be combined into a perceptual compromise (Fenko, 2011). The data analyzed in this study confirm that both of the predicted outcomes occurred. The variance among the judgments suggests that some of the participants ignored either the auditory or the visual information, while in other cases the data from the two senses were taken into account to some extent and resulted in some kind of an intermediate percept.

The qualitative data show the importance of sound mentioned by participants *after* the experiment. When asked the question: “How did you evaluate that this is 1 liter?”, one participant answered: “I wanted to guess from the sound but couldn’t distinguish *a typical sound*.” This participant’s evaluation was a compromise between the two sensory inputs: the video of the tap water showed a strong flow but the sound was of a weak one. Another participant reported: “I counted the first time. Not sure if the flow was really that different this time; *it sounded faster but didn’t look faster*. But I think I pressed too fast.” This participant’s evaluation showed that s/he ignored the visual information and judged according to the sound. Interestingly, the participants noticed the conflicting sensory information *after* the experiment was over but during the experiment they evaluated according to the two predicted outcomes: they either ignored one sense or their evaluation resulted in a perceptual compromise between the two.

The results confirmed that the video had a larger main effect, which supports the existing view that the vision is a dominant sense. Nevertheless, this research showed that auditory information can play a significant role in the evaluation of everyday processes like running tap water, which could serve as the first step in the conceptual development of "smart noisy" faucets.

However, it is suggested to test a regular use of "noisy" faucets in the future experimental studies since this research only focused on one-time use only. For example, it will be interesting to test user experience and evaluation of tap water over a period of time and see after how many uses, the habituation effect appears and for how long it is present. Not less important is to examine the effect of touch as its influence has not been tested in this research. Therefore, more research is needed to test if the same effect of audition still holds in the more realistic setting with the actual measurement of water consumption.

Finally, a possible application of these findings can be used for faucet design for public places. Introducing the taps which would amplify the sound of running water while keeping the flow constant could potentially be an alternative way of saving water. However, since the present research used the videos/audios and not the actual faucets, it is suggested to test prototype taps before the introduction of the "environment-friendly" tap. Also, it is recommended to use such taps in public places, such as organized events, festivities, or public toilets in train stations or airports, where there is no frequent use per individual because of the possible habituation effect. It is possible that after several uses, individuals might simply think that this is just a "noisy" tap and not be affected by the conflicting information from the two senses. Nevertheless, if the actual product testing shows similar results but only for infrequent use, then there are still numerous application opportunities to use the "smart noisy" faucet in diverse public spaces.

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