

Modifying action sounds influences people's emotional responses and bodily sensations

Leandro Miletto Tonetto

Universidade do Vale do Rio dos Sinos, Rua Luis Manoel Gonzaga, 744, Porto Alegre, CEP 90480-200, Brazil;
e-mail: ltonetto@gmail.com

Cristiano Porto Klanovicz

Universidade do Vale do Rio dos Sinos, Rua Luis Manoel Gonzaga, 744, Porto Alegre, CEP 90480-200, Brazil;
e-mail: cristiano.klanovicz@gmail.com

Charles Spence

Crossmodal Research Laboratory, Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford, OX1 3UD, England; e-mail: Charles.Spence@psy.ox.ac.uk

Received 20 February 2014; in revised form 26 June 2014; published online 31 July 2014

Abstract. We report an experiment designed to investigate the effect of modifying the sound of high-heeled shoes on women's self-reported valence, arousal, and dominance scores, as well as any changes to a variety of measures of bodily sensation. We also assessed whether self-evaluated personality traits and the enjoyment associated with wearing heels were correlated with these effects. Forty-eight women walked down a "virtual runway" while listening to four interaction sounds (leather- and polypropylene-soled high-heeled shoes contacting ceramic flooring or carpet). Analysis of the questionnaires that the participants completed indicated that the type of sonic interaction impacted valence, arousal, and dominance scores, as well as the evaluated bodily sensations. There were also correlations between these scores and both self-evaluated personality traits and the reported enjoyment associated with wearing high heels. These results demonstrate the effect that the sound of a woman's physical interaction with the environment can have, especially when her contact with the ground while walking makes a louder sound. More generally, these results demonstrate that the manipulation of product extrinsic sounds can modify people's evaluation of their emotional outcomes (valence, arousal, and dominance), as well as their bodily sensations.

Keywords: multisensory perception, auditory perception, sonic interaction, user experience, consumer behaviour.

1 Introduction

Interest in the study of multisensory perception has grown dramatically over the last decade or so (see Bremner, Lewkowicz, & Spence, 2012; Calvert, Spence, & Stein, 2004; Stein, 2012, for reviews). One particularly fascinating area of research interest involves the study of those interactions between touch/haptics and audition (see Gallace & Spence, 2014, for a review)—in particular, looking at how the sounds resulting from our interaction with the objects and surfaces in the environment influence our perception of the feel and qualities of those items (e.g., Byron, 2012; Spence & Zampini, 2006).

Tajadura-Jiménez et al. (2012) have, for instance, demonstrated that changing the auditory feedback that a person hears when tapping a table can give rise to the impression that their arm is significantly longer than it actually is. Meanwhile, Senna, Maravita, Bolognini, and Parise (2014) recently built on earlier studies of "the parchment skin illusion" (Guest, Catmur, Lloyd, & Spence, 2002; Jousmäki & Hari, 1998) to show that if the nature of the sound that participants heard synchronized with the tapping on their own arm was changed, they reported that their arm felt like it had turned to marble. Hence, while people typically give little consideration to the sounds that result from their interaction with the environment, a growing body of empirical research now shows that action-related sounds do indeed provide a rich source of information that influences our multisensory perception of a variety of product attributes. This would appear to be true no matter whether people realize it or not (e.g., Byron, 2012; Spence & Zampini, 2006; Zampini, Guest, & Spence, 2003).

Aglioti and Pazzaglia (2010) have highlighted the fact that actions are connected to sounds, since the actions of others can be represented auditorily. So, for instance, Ro, Hsu, Yasar, Elmore, and Beauchamp (2009) reported on a series of experiments designed to investigate the influence of auditory cues on somatosensory perception. Their research demonstrated that people's tactile perception

could be profoundly influenced by auditory cues, thus suggesting that similar coding mechanisms are likely to underlie information processing in the two modalities.

Meanwhile, Wilson, Reed, and Braida (2009, 2010) have also demonstrated near-threshold level auditory and tactile tonal stimuli when presented simultaneously in objective detection contexts, reinforcing the existence of interaction between auditory and tactile perceptions. Similar findings have also been reported by Yau, Olenczak, Dammann, and Bensmaia (2009). The latter researchers demonstrated that audition could interfere with tactile frequency perception. Thus, auditory and tactile frequency channels appear to be fundamentally linked.

In recent years, designers have started to become interested in trying to influence the experience of the consumer by means of product sound interactions (e.g., Quinn, 2012). Focusing on the semantic attributes of product sounds, Özcan and van Egmond (2012) were able to identify eight factors that underlie people's semantic associations with product sounds: Attention, roughness, smoothness, temporal constancy, familiarity/unfamiliarity, unpleasantness, machinery, and power. Perceptual factors (attention, roughness, smoothness, and temporal constancy) were found to be correlated with cognitive factors (power, machinery, and familiarity/unfamiliarity) and with more emotional factors (unpleasantness). Product sounds evoke meaningful associations; they can also exert a profound influence over a consumer's ultimate product experience.

It can therefore be argued that sound should be considered as an integral part of the multisensory experience for many products categories. In the field of product design, Schifferstein and Hekkert (2008) have stated that design should be concerned with enhancing product experience through sound. The sound of a product can be manipulated to be more pleasurable, or to be quieter (silent, even; see McDermott, 2013). That said, a near-silent Hoover provides an example of a seemingly desirable product attribute, but one that failed when actually launched in the marketplace (see Wolkomir, 1996). Schifferstein and Hekkert have also pointed out that specific sounds might be associated with particular products (or categories of product), and with distinct meanings, such as being fun, informative, playful, inspiring, even. This means, in our example, that the sound of the Hoover might also be desirable, if the noise is in terms of its cleaning power within the target consumer group.

When it comes to technology and the role of sound (or auditory cues) in retail fashion contexts, it has recently been demonstrated that people spend significantly longer (by about a third) interacting with an augmented reality (AR) clothing display when realistic clothing sounds were presented when their participants tried on various winter jackets (Ho, Jones, King, Murray, & Spence, 2013). Interestingly, the participants in this particular study also reported that they would be willing to spend more on purchasing the garment than when they only received visual feedback (as is typically the case in the majority of AR clothing applications that are currently available).

Knöferle (2011, 2012) has pointed out how people's evaluation of a product (such as the taste of a cup of coffee) can be modified by the manipulation of product extrinsic sounds (in this case, the sound that the coffee maker makes). This effect was moderated by the consumer's enjoyment of the sound of the preparation of the coffee (Houghton, 2014). Thus, it would seem reasonable to assume that the sonic interaction between artefacts and between artefacts and other environmental stimuli can influence the degree of pleasantness in a particular retail shopping experience. That said, it is important to note that individuals tend to differ in terms of their enjoyment of the (artificial) sound of products, according to their personal/cultural backgrounds (Özcan & van Egmond, 2012). Besides the well-mapped connections that have been reported in the literature thus far between sound and emotion, a few other studies have offered a basis on which to ground this idea firmly on the basis of empirical data. Bowles (2013, p. 98), for example, has reported that workers at Hermès "spent three seasons finding the perfect sound a bag should make when it shuts."

Researchers have looked at the type of flooring as one salient factor concerning the environment sounds that are elicited as a result of a shopper's interaction with specific products. Meyers-Levy, Zhu, and Jiang (2010) examined the relationship between bodily sensations and the type of flooring during shopping. They reported that a sense of comfort could be promoted in people simply by means of the presence of soft carpeting while a hard tile floor was more likely to give rise to feelings of fatigue instead.

Bresin, de Witt, Papetti, Civolani, and Fontana (2010) demonstrated that the sound feedback of footsteps can influence human behaviour. Subjects were asked to walk using sensor shoes (for providing auditory feedback) with four emotional intentions: happy, sad, aggressive, and tender. The authors manipulated the ground sound texture four times for each emotion: wood panels, linoleum,

muddy ground, and iced snow. Users tended to a faster pace (more active walking) when they listened to walking surface sounds characterized by a higher spectral centroid (such as iced snow), and a slower pace (less active walking) when the sound of the walking surface had a lower spectral centroid (e.g., muddy ground). More aggressive walking styles were found when participants listened to harder texture sounds, and more tender and sad walking patterns when they listened to the softer sounds.

Based on the literature reviewed above, it is clear that the sound made by products can evoke meaningful associations in the minds of consumers (Özcan & van Egmond, 2012). Furthermore, by providing or manipulating extrinsic product-related sounds, it is possible to change people's perception of them, an effect that will likely be moderated by their enjoyment of these sounds (Ho et al., 2013; Knöferle, 2011, 2012) and/or by their personal/cultural background (Özcan & van Egmond, 2012).

As seen in those studies reported by Meyers-Levy et al. (2010), the floor itself can play a particularly interesting role in terms of moderating people's product experience and preferences. In the present study, we were especially interested in the multisensory experience of consumers in the context of a retail shoe store. We investigated whether the sound of women walking across different types of flooring while hearing high heels would affect their emotional experience and bodily sensations. Here it is interesting to note that certain shoe designers already purportedly play with the material of the heels of the shoes design in order to change the sound that the shoe makes (cf. Quinn, 2012).

Therefore, in the present study, we studied the nature of any sonic interactions taking place between the material of the heel of a pair of high-heeled shoes (polypropylene vs. leather) and the type of flooring (ceramic vs. carpet). Our choice of stimuli was motivated by trying to use materials that are commonly found in shoes and stores, as well as producing louder and quieter contact interaction sounds. The results reported here help to advance our current knowledge by bringing information concerning how the manipulation of the materials that may be used in real-world environments, such as stores, can change auditory stimuli (interaction sounds) and consequently consumer experience.

To date, there have not been any specific studies on this subject. As such, there is a need to frame general hypotheses about what might be found in this study, based on the tangentially related studies mentioned above. The experiment reported here was specifically designed to test the general hypothesis (H1) that the type of sonic interaction that a woman hears while walking would impact on her self-reported valence, arousal, and dominance (VAD) scores, as well as possibly a variety of measures of bodily sensation. Louder sonic interactions (for example, as resulting from someone walking across a ceramic floor with polypropylene soles) were expected to evoke higher VAD scores, whereas quieter walking sounds (resulting from someone walking across a carpet in leather-soled shoes) were expected to evoke higher scores on the bodily sensation scales instead. Considering the possible relation of diverse personal consumer backgrounds on the experience of the user, we also predicted that self-reported consumer styles would be correlated with influences that these sounds had on women: (H2) there is a positive correlation between how much a woman likes high-heeled shoes and VAD scores only in the case of noisier sonic interactions; (H3) there are correlations between the self-evaluated characteristics of "introverted" and "discreet" and VAD scores to quieter sonic interactions; and (H4) there are correlations between the self-evaluated characteristics of "attractive" and "feminine" and VAD scores generated in response to louder sonic interactions. Even though these hypotheses are grounded in literature that is not specifically connected to the manipulated stimuli, it is reasonable to believe that product sounds can change people's experience, and that they are moderated by their enjoyment of these sounds and by their personal/cultural background (Ho et al., 2013; Knöferle, 2011, 2012; Özcan & van Egmond, 2012), such as personality traits.

2 Methods

A within-participants experimental design was utilized. Forty-eight female participants were recruited with a mean age of 23.5 years ($SD = 6.6$ years), a mean height of 1.64 m ($SD = 0.76$ m), a mean weight of 60.6 kg ($SD = 9.2$ kg), and a mean body mass of 22.5 (ranging from 18.8 to 26.6). The experiment took place in a design lab, with the participants tested individually. The entire experiment took between 45 minutes and an hour to complete.

The participants were personally invited to volunteer for the study by one of the authors, in an academic environment, with the authorization of the directors of the department. The experiment was carried out in accordance with the relevant institutional and national regulations and legislation, with the World Medical Association Helsinki Declaration.



Figure 1. Virtual runway used in the experiment reported here.

The sounds of the four types of sonic interaction were recorded in a studio setting that had been treated so as to avoid acoustic distortion. A Zoom H4N recorder was used to register the audio in 96 kHz/24 bits, converted to 44.1 kHz/16 bits, due to compatibility with CD reproduction systems. The same young adult female, using the same high-heeled shoe in two versions (leather and polypropylene soles), walked across ceramic and carpet flooring to generate the sounds to be tested, which were recorded as stereo files using a pair of Neumann diaphragm condenser microphones (Model KM 184) using the XY technique.

Before the experiment, at the moment they arrived at the design lab, the female participants responded to a preliminary questionnaire, concerning their weight, height, and age. The questionnaire also included a question about how much the respondent liked wearing high-heeled shoes (scale from 0 to 10); and self-reported user styles (measured by 5-point semantic differential scales—from -2 to $+2$: introverted \times extroverted, discreet \times indiscreet, attractive \times repulsive, feminine \times masculine; inspired by the Product Personality Assignment of Jordan, 2000).

In the experiment itself, the women were informed that they would walk around a “virtual runway” four times and would fill in a second kind of questionnaire four times immediately after each walk, answering questions about how they felt while walking. The runway was built using Makey Makey (<http://www.makeymakey.com/>). It consisted of 12 metal steps (approximately 10 inches wide by 16 inches long), placed in a circular array (see Figure 1) and connected via wires to a computer and fixed on the floor with adhesive tape. When the woman’s feet made contact with the metal plates placed on the floor, they heard the sounds synchronized with their steps, played back via the computer’s loudspeaker (an Apple MacBook Pro), positioned 2 feet from the first step.

In a 2×2 design, participants walked barefoot over the runway. Each one of the four sounds was played to each participant, in a random order. To be exposed to each sound, each woman walked a total of 12 steps, while listening to the same sound 12 times (i.e., once with each step).

After being exposed to a sound, they filled in the questionnaire. The female participants were asked to respond how they felt listening to the sound, describing the sensations that they experienced (not judging the shoes or the sounds themselves). The dependent measures were valence, arousal, and dominance, and bodily sensations.

Valence (the degree of pleasantness of a stimulus), arousal (the intensity of the emotional response evoked by a stimulus), and dominance (the degree of control experienced by the person facing a stimulus) (VAD) were measured using the self-assessment scale—SAM (self-assessment Manikin) (Badley & Lang, 1994). In this technique, the participants rate their current emotional state via three scales, which are, according to the authors, the three main dimensions of affect. Participants were presented to the question: How did you feel while you listened to the sound of this high-heeled shoe? SAM is a pictorial assessment technique, shown in Figure 2, to measure the three variables, using a 9-point scale, from -4 to $+4$.

Bodily sensations were measured using an instrument from Meyers-Levy et al. (2010). Participants were presented to the following question: Concerning your bodily sensations, evaluate how you felt while listening to the sound of this high-heeled shoe, rating the following items from 1 (not at all)

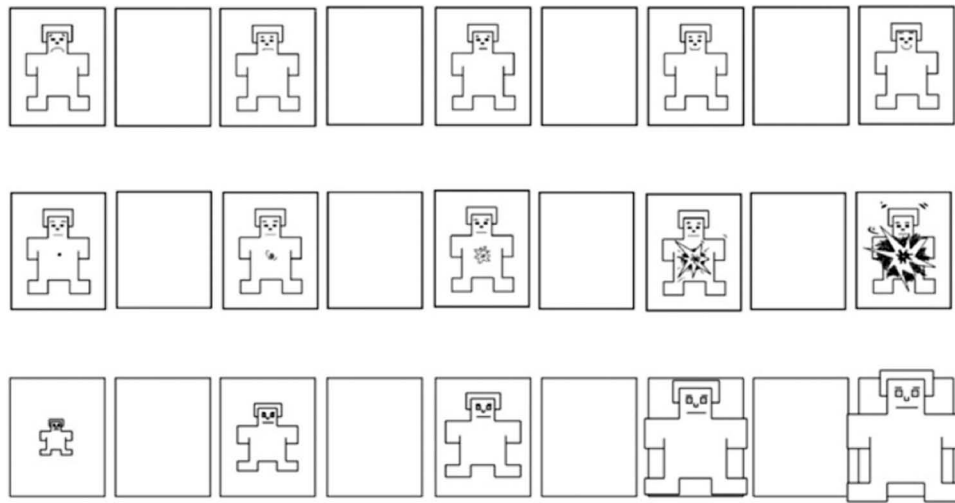


Figure 2. The SAM: Pictorial ratings of valence (top panel), arousal (middle panel) and dominance (bottom panel) (Badley & Lang, 1994).

to 7 (very much). The items were comfortable, softly relaxed, physically supple, at ease, contented, and restful.

3 Results

Table 1 shows results of SAM scores, compared by type of sonic interaction (polypropylene or leather sole versus ceramic floor or carpet).

There is an effect of the type of floor on valence ($F(1, 46) = 17.07, p < 0.001$). Post hoc analyses further revealed that valence was higher when participants heard sounds generated by ceramic floor (1.04), as compared to the carpet (-0.46) ($p < 0.001$).

The effect of floor was also detected for the arousal scores ($F(1, 46) = 23.62, p < 0.001$). Post hoc analyses indicate higher arousal when participants were exposed to sounds produced by ceramic (1.18), as compared to carpet (0.38) ($p < 0.001$). There was also an interaction effect between the type of floor and kind of sole, when observing arousal scores ($F(1, 46) = 5.64, p < 0.05$). Post hoc analyses indicate:

- a) Arousal scores when hearing the polypropylene/ceramic sound (1.49) were higher than listening to leather/ceramic (0.87) ($p < 0.05$);
- b) Arousal scores when listening the polypropylene/ceramic interaction sound (1.49) were higher than when exposed to polypropylene/carpet sound (-0.64) ($p < 0.001$);
- c) Arousal scores when hearing leather/ceramic sound (0.87) were higher than listening to leather/carpet (-0.13) ($p < 0.001$).

For the dominance scores, an effect of the type of flooring was detected ($F(1, 46) = 5.89, p < 0.05$). Post hoc analyses show higher dominance when participants listened to sounds created by the

Table 1. SAM mean scores and SD by type of sonic interaction ($N = 47$).

| Sonic interaction | Valence | | Arousal | | Dominance | |
|--------------------|----------|-----------|----------|-----------|-----------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Ceramic | | | | | | |
| Polypropylene sole | 0.79 | 1.98 | 1.49 | 1.80 | 0.94 | 1.87 |
| Leather sole | 1.30 | 1.97 | 0.87 | 2.08 | 1.51 | 1.60 |
| Carpet | | | | | | |
| Polypropylene sole | -0.47 | 2.00 | -0.64 | 1.95 | 0.64 | 1.86 |
| Leather sole | -0.45 | 1.92 | -0.13 | 1.78 | 0.21 | 1.69 |

Table 2. Bodily sensations mean ratings and SD by type of sonic interaction ($N = 48$).

| Sonic interaction | Comfortable | | Softly relaxed | | Physically Supple | | At ease | | Contented | | Restful | |
|--------------------|-------------|-----------|----------------|-----------|-------------------|-----------|----------|-----------|-----------|-----------|----------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Ceramic | | | | | | | | | | | | |
| Polypropylene sole | 4.33 | 1.53 | 3.85 | 1.44 | 3.94 | 1.56 | 4.08 | 1.72 | 4.40 | 1.80 | 3.31 | 1.57 |
| Leather sole | 4.67 | 1.55 | 4.15 | 1.62 | 4.08 | 1.57 | 4.63 | 1.68 | 5.10 | 1.64 | 3.63 | 1.51 |
| Carpet | | | | | | | | | | | | |
| Polypropylene sole | 4.19 | 1.83 | 4.04 | 1.52 | 4.02 | 1.59 | 4.38 | 1.86 | 3.75 | 1.77 | 3.60 | 1.50 |
| Leather sole | 3.83 | 1.80 | 3.48 | 1.64 | 3.63 | 1.65 | 3.67 | 1.69 | 3.19 | 1.63 | 3.25 | 1.56 |

interaction between any sole and ceramic (1.22), when compared to carpet (0.43) ($p < 0.05$). There was also an interaction between type of floor and kind of sole, when observing dominance scores ($F(1, 46) = 7.02, p < 0.05$). Post hoc analyses also indicated:

- Dominance scores when hearing the leather/ceramic sound (1.51) were higher than listening to polypropylene/ceramic sonic interaction (0.94) ($p < 0.05$);
- Dominance scores when hearing the leather/ceramic sound (1.51) were higher than when exposed to leather/carpet interaction sound (0.21) ($p < 0.001$).

Valence and dominance ratings were positively correlated for the four evaluated stimuli: ceramic/propylene (0.672, $p < 0.01$), ceramic/leather (0.752, $p < 0.01$), carpet/polypropylene (0.658, $p < 0.01$), and carpet/leather (0.597, $p < 0.01$). Other significant correlation patterns among the dependent measures themselves were not detected.

The results of the bodily sensations ratings, compared by type of sonic interaction (polypropylene or leather sole versus ceramic floor or carpet), are shown in [Table 2](#).

For the “comfortable” ratings, an interaction effect of the sole/floor contact sound was observed ($F(1, 47) = 5.66, p < 0.05$). Post hoc analyses indicate that the sound of leather/ceramic (4.67) evoked higher ratings than leather/carpet (3.83) ($p < 0.001$). Ratings of “softly relaxed” also indicated an interaction sole/floor ($F(1, 47) = 7.42, p < 0.05$). Post hoc results indicate that the sound of polypropylene/carpet (4.04) had superior results than leather/carpet (3.48) ($p < 0.001$).

For “physically supple,” no significant differences were reported.

Observing the “at ease” results, an interaction sole/floor was detected ($F(1, 47) = 12.03, p < 0.001$). Differences were found, reported by post hoc analyses:

- The leather/ceramic sound (4.63) evoked higher “at ease” ratings than polypropylene/ceramic (4.08) ($p < 0.05$);
- The polypropylene/carpet sound (4.38) evoked higher scores than leather/carpet (3.67) ($p < 0.05$).

Ratings for “contented” indicate a significant effect of the type of flooring ($F(1, 47) = 17.94, p < 0.001$). Higher scores were observed when the participants listened to sounds of shoes interacting with ceramic flooring (4.75) than with carpet (3.47) ($p < 0.001$). An interaction effect of the sole/floor contact was also detected ($F(1, 47) = 18.64, p < 0.001$):

- The leather/ceramic (5.10) sound gave rise to higher ratings than the polypropylene/ceramic sound (4.40) ($p < 0.05$);
- The polypropylene/carpet interaction sound evoked higher ratings than interaction resulting from the combination of leather/carpet (3.19) ($p < 0.05$);
- The sound of leather/ceramic (5.10) gave rise to higher evaluations than the leather/carpet sound (3.19) ($p < 0.001$).

For the “resentful” evaluations, a sole/floor ($F(1, 47) = 5.88, p < 0.05$) interaction was detected. Scores were marginally significantly higher, when the women listened to the sound of polypropylene/carpet (3.60) than to the sound of leather/carpet (3.25) ($p < 0.074$).

Summarizing the results observed in [Table 2](#), it can be seen that the sounds of any sole touching ceramic evoked higher “contentedness” scores than those from contact with carpet; the leather/

Table 3. Correlations (Sig. 2 tailed) between how much the user likes using heeled shoes and SAM ratings ($N = 46$).

| | Sonic interaction | | | |
|-----------|----------------------------|----------------------|---------------------|---------------------------|
| | Polypropylene sole ceramic | Leather sole ceramic | Leather sole carpet | Polypropylene sole carpet |
| Valence | 0.317* | 0.368** | -0.257 | -0.076 |
| Arousal | 0.068 | 0.246 | 0.027 | -0.058 |
| Dominance | 0.238 | 0.338* | -0.114 | -0.319* |

Note. Significant correlations between how much the user likes high-heeled shoes and SAM scores at *0.05 and **0.01 levels are indicated.

ceramic sound generates higher scores than leather/carpet (measures: “comfortable” and “contented”) and than polypropylene/ceramic (measures: “at ease” and “contented”); and the polypropylene/carpet interaction sound generates higher evaluations than the leather/carpet sound (measures: softly relaxed, at ease, contented, and resentful).

[Table 3](#) shows Spearman correlation coefficients between how much the participant liked wearing heels and their SAM ratings.

Positive correlations were observed between how much the female participants liked high-heeled shoes and their valence scores when listening to the sounds of ceramic/polypropylene and ceramic/leather (the two louder sounds).

The results also highlighted the existence of a positive correlation between how much the participants liked high heels and their rating of dominance when listening to the sound of ceramic floors in contact with the leather-soled shoes (one of the two loudest sounds).

Meanwhile, a negative correlation was reported between dominance and how much the participants liked high heels when the participants were exposed to the sound of carpet in contact with the polypropylene sole (one of the quiet interaction sounds).

[Table 4](#) shows Spearman correlation coefficients between self-reported personality traits and SAM ratings. A negative correlation refers to the characteristic on the top of the cells in the first row (introverted, discreet, attractive, and feminine), whereas positive correlations refer to the characteristics on the bottom (extroverted, indiscrete, repulsive, and masculine).

For the loudest sounds (polypropylene/ceramic and leather/ceramic), valence was negatively correlated with attractive versus repulsive self-reported consumer styles, with subjects tending to associate higher valence ratings with femininity. Other correlation patterns were also detected for the evaluation of these sounds:

- Polypropylene/ceramic contact sound: Valence was also negatively correlated with self-evaluated judgements of feminine \times masculine, with participants exhibiting a tendency to associate higher valence ratings with more self-reported femininity.
- Leather/ceramic contact sound: Dominance ratings were negatively correlated to attractive versus repulsive consumer styles, with women tending to associate higher dominance ratings with more self-reported attractiveness.

The leather/carpet sound revealed no correlations with self-reported personality traits, but polypropylene/carpet did. Valence and dominance were negatively correlated with self-reported introversion versus extroversion (higher valence and dominance associated to introversion), and valence was positively correlated with feminine \times masculine self-reported styles (higher valence associated with masculinity).

4 Discussion and conclusions

The results of the present study highlight the profound effect that interaction sounds that a woman makes when walking can exert on both their emotional responses and bodily sensations. Previous research has reported that changing what a person hears can modify their perception of surface texture (Guest et al., 2002; Jousmäki & Hari, 1998; Senna et al., 2014), product efficacy (Spence & Zampini, 2007; see also Byron, 2012), and even the crispness and carbonation of a variety of food and beverage products (Spence, 2012; Zampini & Spence, 2004, 2005).

Table 4. Correlations (Sig. 2 tailed) between self-reported personality traits and SAM ratings (N = 47)

| | Introverted versus extroverted | Discrete versus indiscrete | Attractive versus repulsive | Feminine versus masculine |
|-------------------------------|-----------------------------------|-------------------------------|--------------------------------|------------------------------|
| 1. Polypropylene sole ceramic | | | | |
| Valence | -0.054 | 0.057 | -0.390** | -0.430** |
| Arousal | 0.084 | 0.019 | -0.049 | -0.139 |
| Dominance | -0.098 | 0.150 | -0.091 | -0.079 |
| 2. Leather sole ceramic | | | | |
| Valence | 0.156 | -0.029 | -0.557** | -0.266 |
| Arousal | 0.000 | 0.001 | -0.164 | -0.280 |
| Dominance | -0.048 | -0.151 | -0.343* | -0.122 |
| 3. Leather sole carpet | | | | |
| Valence | -0.090 | -0.080 | 0.151 | 0.167 |
| Arousal | 0.141 | 0.160 | -0.117 | 0.117 |
| Dominance | -0.006 | -0.189 | 0.013 | 0.196 |
| 4. Polypropylene sole carpet | | | | |
| Valence | -0.368* | -0.110 | 0.126 | 0.307* |
| Arousal | -0.041 | -0.103 | 0.036 | -0.229 |
| Dominance | -0.292* | -0.183 | 0.227 | 0.277 |

Note. Significant correlations between self-reported personality traits and SAM ratings at *0.05 and **0.01 levels are indicated.

In the present study, we confirmed (H1) that the type of sonic interaction that a woman hears would impact on their self-reported SAM scores, as well as possibly a variety of bodily sensations measures, since in terms of the:

- a) Emotional outcomes: any sole/ceramic combinations (the louder sounds) evoked higher VAD ratings.
- b) Bodily sensations: sounds of contact of ceramic with any sole evoke higher “contented” scores than those from contact with carpet; the leather/ceramic sound generates higher scores than leather/carpet (measures: “comfortable” and “contented”) and than polypropylene/ceramic (measures: “at ease” and “contented”); and the polypropylene/carpet interaction sound generates higher evaluations than the leather/carpet sound (measures: softly relaxed, at ease, contented, and resentful).

An additional finding revealed that valence and dominance ratings were positively correlated in the evaluation of how participants felt listening to any sound. Therefore, the degree of pleasantness evoked by the sound (valence) is correlated to the degree of control experienced by the person facing it (dominance).

Heel/floor interaction sounds also influenced participants’ bodily sensations, reinforcing the results reported previously by other researchers (e.g., Aglioti & Pazzaglia, 2010; Ro et al., 2009), indicating that coding mechanisms in touch and audition might be connected. Hence, not only does the contact with distinct kinds of flooring influence a participant’s bodily sensations, as indicated by the work of Meyers-Levy et al. (2010), but the interaction sounds between heels and the floor can also play a similar role.

In the present study, we also predicted (H2) that there would be a positive correlation between how much women liked high-heels and their SAM scores in the noisier sonic interactions. The correlation between variables, although detected, was not as straightforward and simple as predicted, because of

- a) Noisier interactions: How much a woman likes high-heeled shoes was positively correlated with (1) valence, while listening to the sound of ceramic floors, both interacting with

polypropylene and leather soles, and (2) dominance, while listening to the ceramic/leather impact sound.

- b) Quieter interactions: How much a woman likes high-heeled shoes was negatively correlated with dominance scores, when she is exposed to the carpet/polypropylene impact sound.

Valence was positively correlated with the enjoyment of heels when listening to any sole interacting with ceramic flooring, meaning louder sounds (the distinctive and bold sound of heels). Dominance, in addition, was also positively related to the enjoyment of heels with the leather sole/ceramic floor interaction, but still seems to be connected to the characteristic sound of heels. The mentioned enjoyment was negatively correlated to dominance, when the participants evaluated how they felt while listening to propylene sole/carpet interaction sounds; this fact suggests that this quiet sound (as opposed to the loud sound of any sole interacting with ceramic) does not appeal to those women who enjoy heels because it makes them feel dominant.

Finally, we hypothesized (H3) that there would be a correlation between the self-evaluated characteristics of “introverted” and “discreet” and SAM scores to quieter sonic interactions; and (H4) that there would be correlations between the self-evaluated characteristics of “attractive” and “feminine” and SAM scores to louder sonic interactions. These hypotheses were partially confirmed:

- a) Attractive and feminine were correlated with valence scores, when listening to the polypropylene/ceramic sound.
- b) Attractive was correlated with valence and dominance scores, when listening to the leather/ceramic impact sound.
- c) Introverted was correlated with valence and dominance scores, and masculine (the opposite of feminine in the scale) was associated to valence, when exposed to the polypropylene/carpet impact sound.

People differ in terms of their enjoyment of artificial sounds (Özcan & van Egmond, 2012); personal background, such as their enjoyment of wearing heels, can presumably influence the enjoyment of a characteristic sound of a product. One might also imagine there to be an effect of the woman’s introversion/extraversion (Cain, 2012).

These results indicate that self-reported personality characteristics were correlated with variables such as valence, reinforcing the view that a woman’s personal/cultural background may play an important role in the enjoyment of product sounds. In our study, distinct heel/flooring interaction sounds were correlated with the self-reported personality traits in the study, reinforcing Schifferstein and Hekkert’s (2008) proposal that sounds might be associated with products, indicating meanings such as fun, informative, etc.

The main implications of the results reported here are related to the findings that the type of sonic interaction a woman hears can impact on her emotions and bodily sensations, and that the enjoyment of these sounds depends on personal background (self-reported personality traits) and her enjoyment of heels. It has already been well established that changing product sounds can modify product perception, but this study provides evidence that changing interaction sounds between products and the environment (e.g., heel and floor) can also affect emotional outcomes. Even though the results do not allow the authors to make generalizations to other contexts, they nevertheless advance our understanding concerning how sonic interactions affect multisensory perception and also that this effect is not universal, since results were moderated by individual differences/background.

It is important to highlight the fact that even though the main finding of the study is that the sound of high heels influences women’s experience (especially when they make louder sounds), the known relationship between loudness and emotional reactions (with loud sounds tending to be more arousing), the effect can be related to the intensity of the sound, to the sound of heels itself, or to both factors. Since the enjoyment of using heels and self-reported personality traits moderated results, it seems reasonable to think that the sound of heels itself is the main reason.

A potential limitation with the present study that should be flagged up here is the kind of experimental manipulation (within-participants) that was used, and how this might have drawn the participants’ attention to the experimental manipulation under study. Considering the results, it can be seen as an opportunity to be explored in further research.

Another limitation with the present study that also should be raised here is to investigate just how important the feeling of generating the sounds (e.g., the feeling of agency) is to the effects documented here. Do the sounds themselves have an impact over people, independently from who is making them?

Since only the sound agents (women) were studied (not people around the walker), this offers another opportunity for future research. Furthermore, there may be theoretical interest in investigating how male participants who have never worn high heels would respond to these auditory manipulations of interaction sounds.

Even though the participants may have been aware of the potential discrepancy between their own somatosensory sensations and the auditory feedback that they heard in this study, the rationale that led the authors to the decision to collect data with bare foot subjects was of an applied nature. We did not want the aesthetics properties of the shoes to interfere in their rating, totally isolating the effect of the sound itself on user experience.

Nevertheless, on the basis of the results reported here, the impact of heel/floor interaction sounds on the experience of the user/wearer is undeniable, as is the relation between emotional outcomes and personal characteristics, namely the enjoyment of heels and self-reported personality traits.

Acknowledgments. The authors thank Charles Di Pinto for the technical work (recording the sounds).

References

- Aglioti, S., & Pazzaglia, M. (2010). Representing actions through their sound. *Experimental Brain Research*, 206(2), 141–151.
- Badley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, 25(1), 49–59.
- Bowles, S. P. (2013). Stitch perfect. *Harpers Bazaar*, 97–98.
- Bremner, A., Lewkowicz, D., & Spence, C. (eds.). (2012). *Multisensory development*. Oxford: Oxford University Press.
- Bresin, R., de Witt, A., Papetti, S., Civolani, M., & Fontana, F. (2010). Expressive sonification of footsteps sounds. *Proceedings of ISON, 2010*, 51–54.
- Byron, E. (2012). The search for sweet sounds that sell: Household products' clicks and hums are no accident; Light piano music when the dishwasher is done? *The Wall Street Journal*, October 23, downloaded from http://online.wsj.com/article/SB10001424052970203406404578074671598804116.html?mod=googlenews_wsj#articleTabs%3DarticleX
- Cain, S. (2012). *Quiet: The power of introverts in a world that can't stop talking*. New York: Penguin Books.
- Calvert, G. A., Spence, C., & Stein, B. E. (eds.). (2004). *The handbook of multisensory processing*. Cambridge, MA: MIT Press.
- Gallace, A., & Spence, C. (2014). *In touch with the future: The sense of touch from cognitive neuroscience to virtual reality*. Oxford: Oxford University Press.
- Guest, S., Catmur, C., Lloyd, D., & Spence, C. (2002). Audiotactile interactions in roughness perception. *Experimental Brain Research*, 146(2), 161–171.
- Ho, C., Jones, R., King, S., Murray, L., & Spence, C. (2013). Multisensory augmented reality in the context of a retail clothing application. In K. Bronner, R. Hirt, & C. Ringe (Eds.), *(((ABA))) Audio Branding Academy Yearbook 2012/2013* (pp. 167–174). Oxford and Baden-Baden: Nomos.
- Houghton, L. (2014). Costa express launches 'Marlow' self-service coffee. *BigHospitality*, downloaded from <http://www.hospitalityandcateringnews.com/2014/04/costa-express-revolutionises-self-serve-coffee-with-launch-of-marlow/> on 18/05/2014.
- Jordan, P. (2000). *Designing pleasurable products*. London: Taylor & Francis.
- Jousmäki, V., & Hari, R. (1998). Parchment-skin illusion: Sound-biased touch. *Current Biology*, 8(6), 869–872.
- Knöferle, K. M. (2011). Acoustic influences on consumer behavior: Empirical studies on the effects of in-store music and product sound. Dissertation, University of St. Gallen, School of Management, Economics, Law, Social Sciences, and International Affairs. Available at <[http://verdi.unisg.ch/www/edis.nsf/SysLkpByIdentifier/3964/\\$FILE/dis3964.pdf](http://verdi.unisg.ch/www/edis.nsf/SysLkpByIdentifier/3964/$FILE/dis3964.pdf)> [Accessed 10 July 2012]X
- Knöferle, K. M. (2012). Using customer insights to improve product sound design. *Marketing Review St. Gallen*, 29(2), 47–53.
- McDermott, K. (2013). Modern express kettles 'can be as loud as an electric drill with decibel levels of 95'. Daily Mail Online, downloaded from <http://www.dailymail.co.uk/news/article-2375084/Modern-express-kettles-loud-electric-drill-decibel-levels-95.html> on 18/12/2013.
- Meyers-Levy, J., Zhu, R. J., & Jiang, L. (2010). Context effects from bodily sensations: Examining bodily sensations induced by flooring and the moderating role of product viewing distance. *Journal of Consumer Research*, 37(1), 1–14.
- Özcan, E., & van Egmond, R. (2012). Basic semantics of product sounds. *International Journal of Design*, 6(2), 41–54.
- Quinn, B. (2012). *Fashion futures*. London: Merrell.

-
- Ro, T., Hsu, J., Yasar, N. E., Elmore, L. C., & Beauchamp, M. S. (2009). Sound enhances touch perception. *Experimental Brain Research*, *195*(1), 135–143.
- Schiffstein, H. N. J., & Hekkert, P. (eds.). (2008). *Product experience*. London: Elsevier.
- Senna, I., Maravita, A., Bolognini, N., & Parise, C. V. (2014). The marble-hand illusion. *PLoS ONE*, *9*(3), e91688. doi:10.1371/journal.pone.0091688
- Spence, C. (2012). Auditory contributions to flavour perception and feeding behaviour. *Physiology and Behaviour*, *107*(4), 505–515.
- Spence, C., & Zampini, M. (2006). Auditory contributions to multisensory product perception. *Acta Acustica United With Acustica*, *92*(6), 1009–1025.
- Spence, C., & Zampini, M. (2007). Affective design: Modulating the pleasantness and forcefulness of aerosol sprays by manipulating aerosol spraying sounds. *CoDesign*, *3*(Suppl. 1), 109–123.
- Stein, B. E. (ed.). (2012). *The new handbook of multisensory processing*. Cambridge, MA: MIT Press.
- Tajadura-Jiménez, A., Väljamäe, A., Toshima, I., Kimura, T., Tsakiris, M., & Kitagawa, N. (2012). Action sounds recalibrate perceived tactile distance. *Current Biology*, *22*(13), R516–R517.
- Wilson, E. C., Reed, C. M., & Braidia, L. D. (2009). Integration of auditory and vibrotactile stimuli: Effects of phase and stimulus-onset asynchrony. *Journal of the Acoustical Society of America*, *126*(4), 1960–1974.
- Wilson, E. C., Reed, C. M., & Braidia, L. D. (2010). Integration of auditory and vibrotactile stimuli: Effects of frequency. *Journal of the Acoustical Society of America*, *127*(5), 3068–3083.
- Wolkowicz, R. (1996). Decibel by decibel, reducing the din to a very dull roar. *Smithsonian Magazine*, 56–65.
- Yau, J. M., Olenczak, J. B., Dammann, J. F., & Bensmaia, S. J. (2009). Temporal frequency channels linked across audition and touch. *Current Biology*, *19*(7), 561–566.
- Zampini, M., Guest, S., & Spence, C. (2003). The role of auditory cues in modulating the perception of electric toothbrushes. *Journal of Dental Research*, *82*(11), 929–932.
- Zampini, M., & Spence, C. (2004). The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of Sensory Science*, *19*(5), 347–363.
- Zampini, M., & Spence, C. (2005). Modifying the multisensory perception of a carbonated beverage using auditory cues. *Food Quality and Preference*, *16*(6), 632–641.