



Putting salient vocalizations in context: Adults' physiological arousal to emotive cues in domestic and external environments

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ARTICLE INFO

Keywords:

Salient vocalization
Infant cry
Infant laugh
Adult cry
ECG
Context perception

ABSTRACT

Salient vocalizations are automatically processed and distinguished from emotionally irrelevant information. However, little is known of how contextual, gender and attentional variables interact to modulate physiological responses to salient emotive vocalizations. In this study, electrocardiogram (ECG) was utilized to investigate differences in peripheral nervous activity of men and women to infant cry (IC), infant laughter (IL) and adult cry (AC) in two different situational contexts: the domestic environment (DE) and the outside environment (OE). As the mental state of listeners can affect their response to vocalizations, a between-subject design was applied: one group was instructed to *imagine being inside the scenes* (Task 1: explicit task), and the other group was told to *look at the scenes* (Task 2: implicit task). Results revealed that females exhibited lower inter-beat interval (IBI) index in the OE condition, as compared to both males in OE and females in DE conditions, suggesting greater physiological arousal amongst females in response to vocalizations in an outside environment. Additionally, Task 1 revealed that males demonstrated higher Low Frequency/High Frequency (LFHF) index towards AC than IL. Task 2 showed the same association between these two sounds in females. The implicit task also elicited lower LFHF index in response to both IL and IC than control sound (CS), only amongst females. Findings highlight the important roles that contextual information and cognitive demand play in regulating physiological responses to salient emotive vocalizations. Integrated perspectives of physiological responses to emotive vocalizations that consider the influence of internal (adult mental states) and external (environment) contextual information will provide a better understanding of mechanisms underlying emotional processing of salient social cues.

1. Introduction

1.1. Salient vocalizations and the autonomic nervous system (ANS)

In a world filled with noise that hardly ceases, the individual is assailed with salient and non-salient acoustic stimuli on an everyday basis. To distinguish salient emotive vocalizations from inessential cues, our attention effectively captures emotionally relevant information, while irrelevant ones are automatically filtered from the processing stream [13,51,102,105]. From amongst the wide spectrum of human acoustic events, those found to be perceived as most salient are positive and negative vocalizations produced by infants [26,94,128,151], as well as mature emotive sounds that convey distress [144].

The human cry, from infancy to adulthood, has evolved to represent a salient call of distress that signals a potentially threatening situation,

urging a prompt response [86,88,139]. At birth, infants convey their needs and distress primarily by emotive sounds (crying, laughing, cooing), rendering them largely dependent on caregivers to sensitively perceive and respond to these salient vocal cues [26,94,128,151]. Possessing a specific acoustic pattern [40,43], infant cry carries enormous emotional valence [10,128] that elicits caregiver proximity and triggers caregiving behaviors [148,150,151]. Indeed, adults' responses to infant cry remain one of the most biologically adaptive human behaviors (Bornstein et al., 2017). Across the span of development, children acquire the ability to request for their needs, and audible crying reduces over time [54,111]. In adulthood, although crying is a less frequent occurrence, it remains a salient vocalization that signals distress perhaps more so by its infrequency [144]. Similar to infant cry, adult cry has been shown to initiate a call for action [139] and induce prosocial behaviors from others [61].

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Besides distress cries, laughter, a positively valenced vocalization, is an important signal in social situations, creating an assured environment that facilitates social bonding. Laughter serves as an emotionally relevant stimulus [63], both in the context of adult-adult [57] and parent-infant interactions [97,153]. Indeed, infant laughter evokes joyful emotions, enhances the quality of parenting behaviors [20,58,87], and activates reward centres in the brain [68,69,132].

Reactivity of the autonomic nervous system (ANS), a domain within the peripheral nervous system (PNS) that splits its control across two branches, sympathetic and parasympathetic divisions, is critical in prompting responses to cry [64,91]. Infant cry elicits general physiological arousal in parents and non-parents alike, and in both males and females [48,58]. Enhanced autonomic physiological reactions to infant vocalizations, including increases in skin conductance [44,48,147], heart rate, and blood pressure [17,29,31,44,47,53,141,142,147,151] have been documented. Cry-specific physiological responses, contrasting typical infant cry to modified vocalizations [39,40,125] and atypical cry [41,42], have also been demonstrated.

1.2. Modulation of physiological responses

Given that salient vocalizations elicit instinctive physiological responses, the primary aim of this study is to investigate how task, gender, and context information moderate men's and women's physiological arousal in response to emotionally-relevant sounds. Although valence-specific autonomic patterning has been observed, where negative emotions often elicit greater arousal as compared to positive ones [138], emotion scientists generally concur that physiological activation is not specific to single emotions, and that the association between emotion processing and autonomic nervous system (ANS) activity is modulated by moderator variables [8]. Autonomic responsiveness towards salient vocalizations has been shown to be influenced by task, gender, and context.

Gender interacts with task to modulate autonomic response to salient vocalizations. For example, Rigo et al. [113] found that women who were engaged in a self-referential decision task showed an automatic attention shift to infant cry, whereas men exhibited greater physiological response to female adult cries when they were engaged in a syllabic counting task. These findings suggest that physiological activities underlying responses to salient emotive sounds are possibly modulated by cognitive resource availability. Moderation of responsiveness to salient sounds, particularly infant cry, by gender has been extensively explored [2,3,19,30,113,123,133,152].

Knowledge about how external environmental factors, such as context, modulate adults' physiological reactivity in response to salient vocalizations remains scarce. More than two decades ago, Murray [92] suggested that the context in which an infant's vocalization is heard, as well as cognitive appraisal of the emotive cue, greatly influence the selection of caregiving behaviors. Although limited in number, studies that investigate context effects show its force. In a study that investigated adults' eye movements in context perception, Bornstein et al. [18] found that adults exhibited more fixations to congruent object-context scenes as compared to incongruent ones. Congruent scenes displayed natural object-context relations (e.g. tiger in nature) while incongruent scenes depicted contrasting relations (e.g. tiger in a residential area). The greater number of fixations to congruent scenes suggested that adults are more sensitive to environments with functional relationships.

Given that adults are presented daily with emotionally salient vocalizations in various environmental conditions, the significance of contextual information in governing adults' autonomic nervous system responses to these cues is starkly evident. However, no study has systematically investigated how a domestic environment moderates heart dynamics towards emotive sounds as compared to those generated by an environment outside of the domestic context. This study involves two tasks which only differ in the initial instructions provided: to

imagine being inside scenes (Task 1: Explicit task) and simply *look at the scenes* (Task 2: Implicit task). We explored adults' responses to salient sounds (i.e. infant cry, infant laugh, adult cry) in the two environmental settings. Environments that fall under DE relate to close relationships and personal life and include locations within the private home setting (e.g. living room, kitchen); those in the OE category encompass external-oriented contexts outside of personal life, such as areas accessible to the public (e.g. bus stop, public television lounge).

Adults quickly extract objects from their contexts and selectively attend to them [18] with greater recruitment of top-down processes for selective verification of incongruent material. In line with this reasoning, we hypothesized that participants are more likely to exhibit greater physiological arousal towards salient vocalizations in the OE environment. The OE environment, which features public areas outside of the home environment, is arguably less congruent with infant vocalizations and adult cry (sound-context incongruence) than the domestic home setting of the DE environment (sound-context congruence). With respect to infant vocalizations, observational studies that have investigated parental response to infant cues are often conducted in the home environment (e.g. [1,64]). The occurrence of adult cry is also inextricably linked to the domestic setting. Some of the most established variables linked to adult depression occur within the context of the family environment, including conflict, cohesion, nurturance and emotional warmth at home [55,65,112]. Palese et al. [96] showed that 1 in 6 adult persons living in nursing homes cry daily. As such, due to less sound-context congruence in OE, we expected adults to require greater top-down processing of visual contextual and salient auditory information as compared to the DE condition.

We tested two hypotheses relating to task, gender, and context variables. First, due to less context-sound congruence present in the OE condition, we hypothesized that the physiological response to emotive vocalizations in the OE condition, as compared to DE, will be accompanied by a greater sympathetic nervous system response, indicated by lower IBI, RMSSD and pNN50 values. Second, previous studies have suggested that females may possess an enhanced perception of emotion as compared to males [14,28,35], and as such, we predict that the influence of context would be more prominent in females than males. To test our hypotheses, we measured the averaged interbeat-interval within a specified time window (IBImean), the number of times in which normalized R-R intervals exceeded a criterion in a considered time window (pNN50), the root mean square of successive differences (RMSSD), and an index of sympathovagal balance between the two nervous systems (LFHF).

2. Materials and methods

2.1. Participants

We recruited 33 nulliparous female adults (M age 21.39 ± 2.25 years) and 43 nulliparous male adults (M age 21.63 ± 2.23 years) through Nanyang Technological University. All participants were screened for any existing medical and psychiatric condition which could have interfered with physiological responsiveness to the stimuli. The study was approved by the Psychology Program ethical committee of Nanyang Technological University, and participants gave their informed consent before participating.

2.2. Visual stimuli

In each experimental session, participants were presented with 4 different images within the domestic environment (DE) and 4 different images from the outside environment (OE). Foreground images of persons performing 4 different actions were first sourced and obtained from a public online platform using Google Images Search Engine. The 4 foreground images consisted of people performing the following actions: 1) a woman cooking, 2) a woman texting on the phone, 3) a

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