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# Effects of age and individual experiences on tactile perception over the life span in women

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ABSTRACT

Tactile perception results from the interplay of peripheral and central mechanisms for detection and sensation of objects and the discrimination and evaluation of their size, shapes, and surface characteristics. For different tasks, we investigated this interaction between more bottom-up stimulus-driven and rather top-down attention-related and cognitive processes in tactile perception. Moreover, we were interested in effects of age and tactile experiences on this interaction.

299 right-handed women participated in our study and were divided into five age groups: 18–25 years ($N = 77$), 30–45 years ($N = 76$), 50–65 years ($N = 62$), 66–75 years ($N = 63$) and older than 75 years ($N = 21$). They filled a questionnaire on tactile experiences and rated their skin as either very dry, dry, normal, or oily. Further they performed three tactile tests with the left and right index fingers. Sensitivity for touch stimuli was assessed with von Frey filaments. A sand paper test was used to examine texture discrimination performance. Spatial discrimination was investigated with a tactile Landolt ring test.

Multivariate ANOVA confirmed a linear decline in tactile perceptual skills with age ($F(3, 279) = 76.740$; $p < .000$; $pEta^2 = 0.452$), starting in early adulthood. Largest age effects were found for the Landolt ring test and smallest age effects for the Sand paper test, indicating different aging slopes. Tactile experiences had a positive effect on tactile performance ($F(3,279) = 4.450$; $p = .005$; $pEta^2 = 0.046$) and univariate ANOVA confirmed this effect for the sand paper and the Landolt ring test, but not for the von Frey test. Using structural equation modelling, we confirmed two dimensions of tactile performance; one related to more peripheral or early sensory cortical (bottom-up) processes (i.e., sensitivity) and one more associated with cognitive or evaluative (top-down) processes (i.e., perception). Interestingly, the top-down processes were stronger influenced by age than bottom-up ones, suggesting that age-related deficits in tactile performance are mainly caused by a decline of central perceptive-evaluative capacities rather than by reduced sensitivity.

## 1. Introduction

Tactile perception results from an interplay between bottom-up or stimulus-driven processes and top-down attentional or cognitive processes (Lacey & Sathian, 2008). First of all, the ability to sense a stimulus on the skin is determined by the absolute touch detection threshold (Nevid, 2003). Secondly, spatial and temporal features of tactile stimuli need to be discriminated to identify textures, patterns, forms, or objects (Greenspan & Bolanowski, 1996; Hollins, 2002). Thus, complementary peripheral (Johnson, 2002; Johnson & Hsiao, 1992; Johnson, Yoshioka, & Vega-Bermudez, 2000) and central (Godde, Diamond, & Braun, 2010; Harris, Arabzadeh, Fairhall, Benito, & Diamond, 2006; Hsiao, 2010) mechanisms are involved in tactile stimulus detection and discrimination.

It is well-known that tactile perceptual skills decline with increasing age (Dinse, Tegenthoff, Heinisch, & Kalisch, 2010; Wickremaratchi & Llewelyn, 2005). This decline is associated with changes at all stages of somatosensory processing from periphery to cortex. For example, these changes include altered skin conformance (Bowden & McNulty, 2013), reduced receptor density (Kurth et al., 2000) and nerve conduction velocity (Dorfman & Bosley, 1979), loss of white and grey matter in the brain (Salat et al., 2005), and alterations in the activity and specificity

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of cortical neurons (Godde, Berkefeld, David-Jürgens, & Dinse, 2002; Kalisch, Ragert, Schwenkreis, Dinse, & Tegenthoff, 2009; Lenz et al., 2013). The associated functional decline is expressed by an increase in tactile thresholds (Dinse, 2006; Stevens, 1992; Tremblay, Wong, Sanderson, & Cote, 2003), as well as by reduced accuracy in tactile discrimination tasks (Deshpande, Metter, Ling, Conwit, & Ferrucci, 2008; Master, Larue, & Tremblay, 2010). While most studies only compared young adults with older adults (usually older than 65 years of age), Stevens and Patterson (1995) revealed that tactile spatial acuity in different dimensions, such as length, location, orientation, and discontinuity, starts declining early in life with a rate of about 1% per annum between ages 20 and 80. More recent studies confirmed that the described age-related decline in tactile perception can be observed already during middle adulthood, that is, between 30 and 60 years of age (Kaneko, Asai, & Kanda, 2005; Reuter, Voelcker-Rehage, Vieluf, & Godde, 2012; Reuter, Voelcker-Rehage, Vieluf, Winneke, & Godde, 2013; Voelcker-Rehage, Reuter, Vieluf, & Godde, 2013).

It has been well established that individual tactile sensitivity and perception at all ages strongly depend on accumulating effects of use or disuse (Bowden & McNulty, 2013; Dinse et al., 2010). Particularly, extensive daily tactile stimulation as in musicians or blind Braille readers (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Legge, Madison, Vaughn, Cheong, & Miller, 2008; Ragert, Schmidt, Altenmüller, & Dinse, 2004) or in professionals such as surgeons, opticians, or fine mechanics (Reuter, Voelcker-Rehage, Vieluf, Winneke, & Godde, 2014), may attenuate or even prevent age-related decline. Consequently, the magnitude of age-related changes in tactile and haptic abilities varies greatly between persons (Craig, Rhodes, Busey, Kewley-Port, & Humes, 2010).

Interestingly, in contrast to motor functions including manual dexterity tasks, tactile acuity does not seem to differ between the left and right hand in young adults (e.g., Sathian and Zangaladze, 1996; Van Boven et al., 2010; Vega-Bermudez and Johnson, 2001). However, for older adults (over 65 years), but not younger adults (< 56 years), Dinse et al. (2006) reported better performance with left than right index finger in a two-point discrimination task.

It has been revealed that intrahemispheric and interhemispheric inhibition is altered in older adults (Brodoehl, Klingner, Stieglitz, & Witte, 2013; Gröschel et al., 2012), but if and how these changes might be related to changed laterality in tactile perceptual tasks remains open. Moreover, due to a lack of studies in this age group, it is currently unknown when and how changes in tactile laterality develop in middle-aged adults.

With the present study, we investigated how different tactile abilities are affected by age and tactile experiences over the adult life span, from young adulthood to old age. Specifically, our aim was to replicate that age-related changes already occur early in life around age 30 with a nearly linear decline in tactile perception from young to older adulthood (Dinse et al., 2010; Reuter et al., 2012). Individual experiences, specifically the use of the hand on the job or during leisure time, should influence such age effects, particularly in older adults (Reuter et al., 2012, 2014). We further expected the development of a left-hand dominance in tactile discrimination with older age as revealed earlier (Dinse et al., 2006).

Going beyond what has been demonstrated before, we particularly focused on tactile tasks that we assumed to differently involve peripheral or early sensory cortical (bottom-up) and more cognitive or evaluative (top-down) processes. Herewith, sensing of tactile stimuli in the periphery would rely mostly on skin and receptor characteristics such as shape and density, while the evaluation and classification, i.e., perception of tactile information would be more associated with central (mostly cortical) processes and mechanisms such as cortical neuronal tuning properties, lateral inhibition, or attention and working memory.

Peripheral sensitivity was tested as touch detection threshold with von Frey filaments, a sand paper test was used to examine texture discrimination performance, and spatial discrimination was investigated with a tactile Landolt ring test. Both texture and spatial discrimination are assumed to rely significantly on sensory cortical and cognitive processes (Dinse, 2006; Reuter et al., 2013). Herewith we intended to provide evidence for different tactile tasks to be dependent on different associations with separate peripheral, rather sensory and central, rather perceptual mechanisms. Furthermore, we expected the relative contribution of those mechanisms to tactile perception to change with age (Kalisch, Kattenstroth, Kowalewski, Tegenthoff, & Dinse, 2012).

## 2. Methods

### 2.1. Participants

This study was performed within the framework of a larger project on the effect of age and tactile sensitivity on the perception and evaluation of cosmetic creams (Trautmann et al., 2016). For this study, 299 women in five age groups, 18–25 years ($N = 77$, MEAN $= 21.2$, SD $= 2.2$), 30–45 years ($N = 76$, MEAN $= 39.6$, SD $= 4.10$), 50–65 years ($N = 62$, MEAN $= 57.3$, SD $= 4.91$), 66–75 years ($N = 63$, MEAN $= 69.6$, SD $= 2.73$) and older than 75 years (N = 21, MEAN $= 78.5$, SD $= 4.11$) were recruited from a data base of the three research institutes *Sensory and Marketing (SAM, Hamburg, Germany), proDERM (Schenefeld, Germany)* and *Institut für Sensorikforschung und Innovationsberatung (ISI, Göttingen, Germany)*. They gave their informed consent to participate in the study and received monetary compensation for participating in the study. The study was conducted in accordance with the ethical standards of Jacobs University Bremen and the Declaration of Helsinki on experiments with human participants. All participants reported to be right-handed.

### 2.2. Tactile tests

Three tactile tests were performed in one session lasting about 1 h. The tests were performed with the right and left index finger. Touch detection threshold (TDT) was evaluated by applying 12 von-Frey Filaments (Marstocknervtest, Schriesheim, Germany) with descending thickness, which represented the filament's force from 0.125 to 512 mN in a logarithmic scale. Participants were blindfolded and could not see if a stimulus was applied or not. Three trials per filament were done with variable time intervals and participants simply responded verbally ('yes') when they felt a filament touched upon their finger. Two-down, one-up procedure was used and stopped after six points of return (Leek, 2001). Threshold was defined as the mean of the forces at the six points of return. The log-transformed threshold values from the von Frey test were used for further analysis (variable FREY; cf. Mills et al., 2012).

Touch perception was assessed in two different tests. Firstly, a sandpaper test (Lederman & Klatzky, 1987; Heller, 1989) was used to examine the ability to discriminate the texture of surfaces. During this test, the participants were asked to identify the finer sandpaper within pairs of sandpapers differing in grit values. Grit values between P80 and P400 were used that were logarithmically ascending to follow the Fechner-Weber-Law of perception (Barker, 1930). The test consisted of eight pairs of sandpapers: P80 and P100, P100 and P120, P120 and P150, P150 and P180, P180 and P220, P220 and P240, P240 and P320, P320 and P400 (Heller, 1989). Each pair was presented once to both index fingers. To avoid predictability for the second hand, we presented one out of three different boards in randomized order with randomized localisations of the sandpapers. The variable SAND was calculated as the sum score of correct trials.

Secondly, the tactile Landolt ring test (Bruns et al., 2014; Legge et al., 2008) was applied to identify the individual spatial tactile discrimination threshold. The Landolt rings were embossed on plastic material and had an elevation of 0.4 mm (Bruns et al., 2014). One Landolt ring chart included eleven rows with four to eight rings decreasing in size from row to row. Those rings corresponded to the