Haptic perception and synaesthesia

Jamie Ward, Michael J. Banissy and Clare N. Jonas

Synaesthesia involving haptic perception has been less well documented than other forms of synaesthesia. There are several possibilities why this might be. Firstly, it may well be less common than other types of synaesthesia. Day [1] reports that only 4.0% of synaesthetes report coloured touch and 0.8% report vision-to-touch, compared to 68.8% reporting coloured graphemes (note: these are percentages of synaesthetes, not percentages of general population). A second reason is that researchers don't always ask about touch and synaesthetes don't always volunteer it. We made a chance discovery of someone who experiences tactile sensations on her own body when watching someone else being touched as a result of an email request about other forms of synaesthesia. We have since found that other synaesthetes have it too but they didn't report it until prompted because they considered it 'normal' (i.e., they assumed everyone else had it). Preliminary findings suggest that this could be just as common as grapheme-colour synaesthesia, once considered to be the most prevalent type of synaesthesia [2]. This chapter will review research on these types of synaesthesia and consider their neural and cognitive basis. We will draw particular attention to similarities between synaesthetic perception and multi-sensory perception involving vision and touch.

Synaesthetic perceptions have three defining features. They are *conscious* percept-like experiences that are *involuntary* and are *elicited* by a stimulus that is not normally associated with this experience [3]. The synaesthetic percept coexists with the percept of the inducing stimulus rather than over-riding it. Thus, a tactile stimulus may be perceived as a tactile sensation plus a colour sensation. As such, some have regarded synaesthesia as a special instance of the 'binding problem' in which two stimulus features (one veridical and one illusory) are combined into a unitary experience [4]. The stimulus that elicits the experience has been termed the 'inducer' and the experience itself has been termed the 'concurrent'. Here we use the terminology of referring to different types of synaesthesia in terms of inducer-concurrent pairs separated with a hyphen. Thus, touch-colour synaesthesia refers to tactile inducers eliciting a concurrent experience of colour, and vision-touch synaesthesia refers to a visual inducer eliciting a tactile experience. We have also colloquially referred to the latter as 'mirror touch' synaesthesia given its similarity to mirror systems for action.

Causes and explanations of synaesthesia

Synaesthesia exists in developmental and acquired forms. The developmental form is reported to exist throughout the lifespan and is believed to have a genetic component [2, 5]. It was once considered to be more common in women than men [2], although recent studies cast doubt on this [6]. Different types of synaesthesia co-exist within families and individual synaesthetes often have multiple types of synaesthesia (i.e., multiple inducer-concurrent pairings). Synaesthetic experiences can be temporarily acquired after ingestion of certain hallucinogenic substances [7]. Synaesthesia may also be acquired after sensory deafferentation. For example, sound-vision synaesthesia has been noted to occur in some cases of acquired blindness [8] presumably as a result of cross-modal plasticity that acts as a compensatory mechanism. Loss of haptic perception, following paralysis or amputation, can also be associated with synaesthesia as in the case of visually-induced phantom limb sensations. In this review we will consider both acquired and developmental forms of synaesthesia.

Developmental forms of synaesthesia are typically explained in terms of aberrant connectivity resulting from differences in gene expression [9, 10]. One recent study, using diffusion tensor imaging (DTI), reported greater coherence of white matter tracts in a number of brain regions in grapheme-colour synaesthetes [11]. While some researchers have emphasised that the aberrant connectivity might be relatively localised, restricted to adjacent cortical regions [10], others have postulated a role of long-range connectivity, for example between primary auditory and visual cortices [9]. While there is evidence of long-range multi-sensory connections in the primate brain [12], this does not adequately account for the most common types of synaesthesia. Synaesthesia often involves inducers that are not strictly 'sensory' (i.e., words, numbers, etc.). The adjacency assumption offers some explanation for this. For example, the presence of both grapheme recognition and colour perception mechanisms in left fusiform cortex could be explained by increased localised connectivity between these regions [10].

Ward [13] offers an account of both acquired and developmental forms of synaesthesia in terms of adaptations to normal mechanisms of multi-sensory perception. All types of synaesthesia may be associated with activation of multi-sensory processes *via* a unimodal stimulus (e.g., involved in spatial and temporal binding), but the nature of the inducer-concurrent pairings will depend on the cause of the synaesthesia. Developmental synaesthesia will tend to result in types of synaesthesia in which the inducer and concurrent are processed nearby [10] but acquired synaesthesia reflects neural adjustments (e.g., removal of inhibition, increased synaptic density) within pre-existing multi-sensory circuits. Behavioural evidence for shared mechanisms between synaesthetic perception and normal multi-sensory perception comes from the fact the mapping between inducer and concurrent is non-arbitrary. For example, synaesthetes tend to perceive higher pitched notes as lighter and smaller [14] and non-synaesthetes show evidence of the same tendency when asked to discriminate pitch and ignore surface lightness, or *vice versa* [15]. Comparable evidence in the domain of vision and touch is considered later.

Vision-touch synaesthesia

In this particular type of synaesthesia, the inducer is 'observed touch' rather than vision *per se*. More specifically, in many cases the inducer should more properly be described as 'observed bodily touch'. As such, this type of synaesthesia bears resemblance to the non-synaesthetic literature demonstrating that non-informative observation of body parts can affect haptic perception [16, 17].

Acquired synaesthesia in phantom limbs

Amputation or paralysis of a limb is frequently accompanied by tactile, painful or motoric sensations in the location of the missing limb – a so-called phantom limb. This may be the result of intra-modal plasticity such that stimulation of a region of the cortex surrounding the neural representation of the missing limb (e.g., the somatosensory face area) comes to activate the adjacent neural representation of the missing limb [18]. This dual-percept of tactile stimulation of a veridical and illusory body part resembles synaesthesia, but may not be a true case of synaesthesia given that the inducer and concurrent are of the same kind. However, it is also possible to induce phantom tactile sensations *via* the visual sense and this constitutes a true type of synaesthesia.

Ramachandran and Rogers-Ramachandran [19] used mirrors to create a duplicate image of the amputated hand/arm based on a reflection of the patient's existing hand/arm. Movement or observed touch to the intact hand produced a