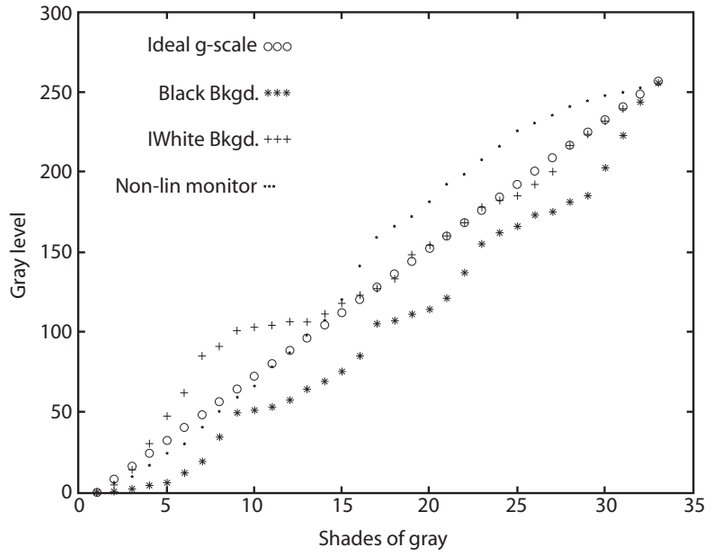

Figure2. Representation of the gray scales created by a non-experienced subject under the same conditions as in Figure 1.

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A FORGOTTEN CONTRIBUTION OF HERBART (1837/1851) TO THE LITERATURE ON THE MEASUREMENT OF SENSATIONS

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Abstract

It was in 1824 that J. F. Herbart (1776-1841) presented the most complete version of his Newtonian model of events involving consciously experienced mental representations (Vorstellungen). In 1837, Herbart wrote a fragment (published posthumously, in 1851) concerning the measurability of Vorstellungen. According to Herbart, mental sensation-Vorstellungen differ quantitatively from the physical objects they represent in not possessing spatial dimensions, and in having magnitudes on a psychological dimension as opposed to a physical dimension (with the boundaries of the former differing qualitatively from those of the latter). Because, in Herbart's model, interactions between Vorstellungen always demand the simultaneous presence of at least two Vorstellungen, Herbart contended that the laboratory measurement of the strength of a single sensation is not necessarily relevant to the establishment of either the validity or the reliability of his model. This opinion anticipated present-day viewpoints such as that of Laming (1997) concerning sensation measurability.

By 1824, a full-fledged system of psychology, incorporating mathematics, had been worked out by Johann Friedrich Herbart (1776 - 1841) in Part 1 of a book entitled *Psychologie als Wissenschaft* [Psychology as science] (Herbart, 1824/1890b). The system had fallen out of favour for most of the 20th century, as explained by Boudewijnse, Murray, and Bandomir (1999, 2001). The fragment here summarized was written in 1837.

Herbart wanted to emulate the success with which Sir Isaac Newton (1642-1727) and his successors had described the world of matter; so Herbart devised a system of psychology that applied Newtonian mathematics to the world of mind. As the mental equivalents of physical 'objects', Herbart used the word *Vorstellungen* (plural); a *Vorstellung* (singular) refers to a mental experience (experienced only by the person having it and not by anybody else at the same time). More than one *Vorstellung* can be experienced by an individual at a given moment. Among 'mental experiences' are included sensations, perceptions, bodily feelings, emotional feelings, mental images, and thinking in words.

G. T. Fechner (1801-1887) may possibly not have known about this fragment. It was first published by Gustav Hartenstein (1808 - 1890), a colleague and friend of Herbart, who undertook the enormous task of editing and publishing Herbart's collected works after Herbart's death in Göttingen in 1841. Hartenstein's edition, which appeared between 1850 and 1852, contains twelve volumes. The first time the present author saw the Hartenstein edition was in the historical building of the Research Library of the 18th Century at the University of Göttingen in September 2004, and he thanks Hermann Kalkofen and Jürgen Jahnke for their assistance in accessing the library and in arranging for a photocopy of the article here summarized.

Hartenstein found this hand-written unfinished fragment (Herbart,1837/1851) among Herbart's papers. Hartenstein reproduced it in volume 7 of his edition along with other miscellanea concerned with psychology. Its apparent date, 1837, puts it firmly after the main exposition of Herbart's mathematical psychology in 1824, and firmly prior to the publication of Fechner's *Elemente der Psychophysik* [Elements of psychophysics] in 1860. The fragment was not included in the 19-volume edition of Herbart's collected works edited by Kehrbach

and Flügel between 1887 and 1912; because the author had used this edition during his early research on Herbart, he had 'missed' the fragment until he spotted it in the Hartenstein edition when he visited Göttingen in 2004.

The Contents of Herbart's 1837 Fragment

The fragment takes the form of a dialogue between two people, A and B. In the dialogue, A represents Herbart and B an opponent who offers real resistance to whatever A asserts. Before summarizing the dialogue, we first indicate where Herbart is heading, namely, towards his key belief that any science of the mind has to be modeled on Newton's science of matter.

In Newton's science, movements of physical objects in space were determined by forces; calculus allowed the magnitudes, and hence the effects, of those forces to be described *briefly*, in a few equations. Newton, in writing the *Principia*, had actually used calculus only occasionally, because, he explained, he preferred to expound his theory using the geometry handed down to his generation by the Ancients (Newton, 1687/1999; Cohen, 1999, pp. 122-127; 316-359). Herbart felt no such constraint when expounding his Newtonian model of the mind and insisted that, no matter how many 'units' of magnitude were assigned to a given *Vorstellung* in practice, the magnitude itself had to consist of units each of which itself could be conceptualized in terms of sub-units that could play the role in Herbart's mental science that infinitesimals had played in Newton's physical science.

But *Vorstellungen* differ in certain important ways from physical objects. First, *Vorstellungen* are mental events that can be related to each other in time, but not in space. Two *Vorstellungen*, *a* and *b*, can be experienced simultaneously or successively. But one *Vorstellung*, *a*, can never be 'to the left of' or 'above' another *Vorstellung*, *b*. On the other hand, two *Vorstellungen* that are experienced simultaneously, if they are identical in sensory content, might be experienced as one *Vorstellung* (for example, two simultaneously sounded and identical tones might be heard as only one tone). If it should happen that they are experienced as two tones identical in sensory content, it would be because the sources of the two sounds were spatially separated and therefore different in spatiotemporal context. Clearly the similarity of two *Vorstellungen* to each other will be determined by two variables, namely, the similarity of their *sensory contents* and the similarity of their spatiotemporal *contexts*.

If two *Vorstellungen* of identical sensory content (e.g. two identical tones) are experienced successively, they might be perceived as a single continuous *Vorstellung* if the interval between them is so short that the ear cannot discriminate that there are two tones. They might also be encoded as a single *Vorstellung* if they should be fused in the perceiver's short-term memory. If the interval between the two tones is long enough, they will initially be perceived as two separate tones, but, a minute later, say, the two individual *Vorstellungen* may have been fused into a single *Vorstellung* in memory.

In his fragment, Herbart chose to discuss the successive sounds experienced by a person who heard twelve bell-strokes in succession. The *Vorstellungen* that remain after the whole series has been heard can vary in number and in magnitude. The number will partly depend on whether the person has grouped them retrospectively using short-term memory, and partly depend on whether the sensory content of the *Vorstellung* of any one bell-stroke was exactly identical to that of every other bell-stroke (as might be the case for a stationary listener) or only nearly identical (as might be the case for a listener moving towards or away from the bell-tower during the twelve bell-strokes). The magnitude of any *Vorstellung* will also depend on these variables, but the estimation of the numerical value of that magnitude presents its own intrinsic problems.

For example, and this is a second issue concerning differences between *Vorstellungen* and physical objects, it is not the case that the magnitude of a given physical object can

necessarily be identified with, or linearly related to, the magnitude of a reasonably veridical mental *Vorstellung* of that same object. A physical distance of one metre between two objects can be represented in a *Vorstellung* the sensory content of which includes representations of the two objects; but the *Vorstellung* itself, being non-spatial, will not itself be one metre in length, nor will it be the case that a mental *Vorstellung* of the same two objects removed from each other by a new distance of three metres, will have a mental magnitude that is three times that of the original *Vorstellung*. Herbart knew that doubling the number of voices in a choir did not necessarily double the subjectively perceived loudness of the choir. The research of Weber (1834/1996) on just noticeable differences in perceived heaviness and in perceived line length had also been published prior to the writing of the fragment. It is not clear from the fragment whether Herbart had read Weber, but we do know from Herbart's published correspondence in Volumes 16 to 19 of the Kehrbach/Flügel edition of his collected works that no letters between Herbart and Weber, or between Herbart and Fechner, have survived.

Third, there are not only *quantitative* differences between the values of physical magnitudes and the values of the *Vorstellungen* representing the physical objects that possess those physical magnitudes. There are also *qualitative* differences that entail that the upper and lower limits of a scale of units used to measure certain characteristics of physical objects cannot necessarily serve as a guide to the corresponding upper and lower limits of a scale of units used to measure the magnitudes of the mental *Vorstellungen* representing those characteristics.

For example, colours can be represented on a physical scale by a continuum of wave-lengths. But on a psychological scale colours, for Herbart, were represented, not by wave-lengths, but by locations on a so-called 'colour circle'. Newton (1704/1952, pp 125-129) had found, in an experiment, a relationship between the seven tones of the diatonic musical scale (now denoted in English as doh, ray, me, fah, soh, lah, te – the next 'doh' is said to be one octave above the first 'doh') and the seven colours obtained when white light is passed through a prism (red, orange, yellow, green, blue, indigo, violet). This particular subdivision of the visible spectrum into seven colours was therefore not arbitrary on Newton's part (see also Boring, 1942, pp. 104-106).

Let the reader imagine a straight line, and let each of these seven colours be assigned, in the above order, to a location on the line, with red at the left end of the line and violet at the right end of the line. Now imagine that the line be grasped at its two ends and bent upward into a circular arc whose two ends are separated by a gap. Red will be on the left, and violet on the right side of the gap. Between them, within the gap, a colour intermediate between red and violet can be *mentally* inserted; such a colour could be named, perhaps, 'purple'. On *this* subjectively scaled colour-circle, violet would be *one* unit away from blue (with indigo intervening) and one unit away from red (with purple intervening). Violet would be *two* units away from green (with indigo and blue intervening) and two units away from orange (with purple and red intervening). Herbart used this example to demonstrate that the units a physicist might use to describe rays of light are not the units a psychologist might use to describe subjectively experienced colours. The units a physicist might use might be wave-lengths and the units a psychologist might use might be the number of intervening prismatic colours as named by Newton. An analogous argument is then applied by Herbart to the auditory modality, where the units a physicist might use to describe tones might be wave-frequencies and the units a psychologist might use might be octaves.

Recapitulating these three differences between physical objects and the corresponding mental experiences, we see that *Vorstellungen* do not have spatial properties. The intensities of mental sensation-*Vorstellungen* are not necessarily linear functions of the intensities of the corresponding sensation-arousing events. And what are measurement continua in physics are not necessarily measurement continua in the corresponding mental experiences.

We now paraphrase the fragment in the light of the above remarks. It should be noted that interlocutor B is set, from the start, to argue that the measurement scale that is used to measure mental magnitudes must satisfy a certain criterion characteristic of the scales used to measure spatial and temporal magnitudes. In the case of spatial extents, if we choose, say, a metre as the measurement unit, it necessarily follows that, if *x* measuring-rods, each exactly one metre long, can be laid end-to-end between two points P and Q, then the distance between P and Q will be *x* metres. B insists that this 'concatenation criterion' be satisfied.

The dialogue begins when A first agrees with B that any measurement scale must have units whose total number may possess a certain upper and lower limit, but A points out that the upper and lower limits of the units of measurements of distance do not necessarily convey much about the nature of space itself. By the same token, a knowledge of the number of units of measurement that constitute a given physical distance need not necessarily convey much about the strength of the mental *Vorstellung* that represents that distance in the mind of an observer. A goes on, with occasional comments by B, to add two corollaries to A's argument. First, a knowledge of the amount of an *increase* in the physical magnitude of a sensory stimulus does not necessarily lead to a knowledge of the amount of *increase* in the mental magnitude of the *Vorstellung* representing that stimulus (the choir example). Second, if a number of *Vorstellungen* are set up sequentially, each ostensibly representing a sensory event whose sensory content is identical to that of each of the remaining events in the sequence (e.g. bell-strokes), then, immediately after the sequence of events has finished, the number of *Vorstellungen* of the whole sequence is not necessarily predicted directly by the number of *Vorstellungen* set up during the perceiving of the sequence.

B prefers not to discuss the role of memory in setting up the post-sequence *Vorstellung* or *Vorstellungen*, and accuses A of having digressed from the main topic of whether a measurement of *Vorstellung* strength can be found that satisfies the concatenation criterion. But when B himself goes on to discuss the bell-stroke example from this point of view, B rather unexpectedly changes from discussing the perception of several intermittent stimuli (such as consecutive bell-strokes) to the discussion of a single continuous stimulus (such as a steady tone). He is led to say that the strength, *V*, of a post-sequence *Vorstellung* can probably be derived if one knows the amount by which *V* would increase during a very short passage of time elapsing during the continuous perceiving of the sequence. That is, B himself *almost* says that, if the magnitude, *V*, of a mental entity is to be a variable in a systematic theory of mental events, it might not only be necessary, but also sufficient, for that magnitude to be defined in such a way that the expression (dV / dt), where *t* denotes time, can be used to make hypotheses within the systematic theory. A seizes his chance and asks whether B is familiar with a previously published article by A (Herbart, 1822/1890a) in which A had expressed a similar opinion.

The last part of the fragment is taken up by A's evidence that the upper and lower limits of the units of a physical scale are not necessarily reliable guidelines to the upper and lower limits of the units of the psychological scale corresponding to that physical scale. A gives examples from the visual modality (colours) and the auditory modality (tones) and, at B's suggestion, is just about to go on to discuss some of the sensations associated with the cutaneous modalities (warmth and heaviness) when the fragment ends.

The Relevance to Psychophysics of Herbart's 1837 Fragment

Here, two reasons will be given for believing that Herbart probably would have found it misleading to presume that a value of the subjective sensation magnitude ascribed to a stimulus S, measured in the laboratory using one of Fechner's methods (or a related method, such as magnitude estimation), can be identified with the magnitude ascribed by Herbart to a sensation-*Vorstellung* to which S gives rise.

In order to introduce the first of these reasons, it is appropriate to note here that both the Newtonian and the Herbartian systems, despite their theoretical advantages, share certain practical drawbacks. In Herbart's system, predictions about future mental events are computationally tractable when it is assumed that there are very few *Vorstellungen* concurrently in consciousness and that the predicted events occur within the next few seconds. In Newton's system, there is an analogous limitation, exemplified by the three-body problem; the difficulty of landing a space vehicle on the moon is in large part due to the difficulty of calculating the successive gravitational forces on each other of three simultaneously moving objects, namely, the space vehicle, the earth, and the moon.

Herbart (1812/1888) himself complained about the limited value of his psychological theory for making predictions about the educational progress of his students over months or years. In fact, he was sceptical about the usefulness of any experimentation in a psychological laboratory because it was so difficult to ensure that any experiments were replicable with the exactitude associated with experiments in the physics laboratory. He felt that it was almost impossible to control intra-individual as well as ambient environmental factors from experiment to experiment.

Herbart's scepticism about the replicability of psychological experiments probably led to what we here consider as the first reason for distinguishing between Fechnerian sensation magnitudes and Herbartian sensation-*Vorstellungen* magnitudes. For Herbart, there was no need to be specific about how to *measure* the magnitude of any one *Vorstellung*. All of his equations were about how the magnitude of each of several *Vorstellungen* concurrently being experienced was raised or lowered depending on the magnitudes of the remaining *Vorstellungen* and on the passage of time. There was no need to specify, by laboratory measurement, the strength of any one individual *Vorstellung* at a particular moment in time; all mental events involve a mutual interaction between at least two *Vorstellungen*; in Herbart's system, at least two *Vorstellungen* are always interacting at any moment.

More recently, Laming (1997), following his book-length review of the Fechnerian and related literature, came to the conclusion that any claim that a given measurement represented the strength of a 'sensation' could equally well be interpreted as a claim that the measurement represented a degree of sensory contrast. Moreover, Laming added that he could find no evidence that any such measurement actually *was* a value on an internal scale that could be called a 'sensation continuum'.

A second reason for distinguishing between Herbart's and Fechner's approaches to sensation- *Vorstellungen* is that Herbart considered that the psychology of 'attention' was determined by the relative magnitudes of the individual *Vorstellungen* concurrently in consciousness and questioned whether a separate 'faculty' of attention was necessary in a scientific psychology. Fechner was less reductionist in his approach.

The following opinion was expressed by the renowned mathematician C. G. J. Jacobi (1804 - 1851): "I have read Herbart's psychology and must confess that, if Herbart was correct in the assumptions that form the starting point of this work, each page of the work has as much value as a page from the natural philosophy of Newton." (quoted by Flügel, 1905/2001, p. 23). Herbart's contribution to the problems of psychophysical measurement ought, it seems to me, to be considered as being of more than mere 'historical interest'.

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DOES AGING AFFECT THE CHANNEL CAPACITY FOR IDENTIFYING PURE TONES DIFFERING ONLY IN INTENSITY?

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Abstract

Murphy et al. (2006) showed that normal-hearing younger and older adults do not differ in their ability to identify a set of eight pure-tones differing in intensity only (52, 58, 64, 70, 76, 82, 88, and 94 dB SPL). Their results suggest that auditory channel-capacity is preserved in aging. However, it is possible that using perfectly discriminable stimuli did not allow age-related differences to surface in Murphy et al's experiment. In the current study, we repeated Murphy et al's experiment using more closely spaced stimuli (60, 61.5, 63, 64.5, 66, 67.5, 69, 70.5 dB SPL), and found that while discrimination was generally poorer, absolute identification was equivalent for both age groups. Our results thus replicate Murphy et al's findings, and suggest that auditory channel capacity is not affected by normal aging even when the ability to discriminate two closely spaced intensities is.

Normal aging is accompanied by auditory declines that can undermine the speech comprehension abilities of older adults. At the peripheral level, cochlear degeneration reduces temporal and spectral resolution of auditory signals, resulting in degraded representations of signals beyond the cochlea (Schneider & Pichora-Fuller, 2000). In cognitively demanding situations, the reallocation of cognitive resources to compensate for these poorer sensory signals might manifest itself as deficits in speech comprehension. However, even older adults with clinically normal audiometric thresholds experience speech-processing difficulties in noisy and/or multi-talker environments. This has led researchers to explore age-related auditory changes beyond the cochlea, and has resulted in an accumulation of evidence pointing toward age-related declines in central auditory processing (Martin & Jerger, 2005). Recently, Murphy, Schneider, Speranza, and Moraglia (2006), investigated potential age-related differences in one attribute of central auditory processing, namely auditory channel capacity. Channel capacity refers to the amount of information that can be transmitted through a sensory channel (i.e., the channel's bandwidth). Miller (1956) showed that auditory channel capacity was limited to 2-3 bits of information for pure tones varying in intensity only. He also showed that this auditory channel capacity was independent of the intensity difference between stimuli, as long as the stimuli used were not too difficult to discriminate. Murphy et al. (2006) measured age-related differences in auditory channel capacity for pure tones varying in intensity only using an absolute identification paradigm. In an absolute identification paradigm, one of a given set of stimuli is presented on each trial, and a listener is asked to "identify" the stimulus by indicating which one of the set of stimuli he or she believes the presented stimulus to be. Murphy et al. (2006) asked normal-hearing younger and older adults to identify sets of 2 to 8 tones (52, 58, 64, 70, 76, 82, 88, and 94 dB SPL) based