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End anchoring in short-term order memory

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ABSTRACT

Temporally grouping lists has systematic effects on immediate serial recall accuracy, order errors, and recall latencies, and is generally taken to reflect the use of multiple dimensions of ordering in short-term memory. It has been argued that these representations are fully relative, in that all sequence positions are anchored to both the start and end of sequences. A comparison of four computational models of serial recall is presented that shows that the extant empirical evidence does not point towards fully relative positional markers, and is consistent with a simpler scheme in which only terminal items are coded with respect to the end of a sequence or subsequence. Results from the application of the models to data from two new experiments varying the size of groups in serially recalled lists support this conclusion.

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Evidence from investigations across psychology, including word recognition (e.g., Davis & Bowers, 2004), economic and valuative judgements (e.g., Hsee, Hastie, & Chen, 2008; Stewart, Chater, & Brown, 2006), spatial representation (Sadalla, Burroughs, & Staplin, 1980) and perception and absolute judgement (e.g., Bressan, 2006; Gravetter & Lockhead, 1973; Stewart, Brown, & Chater, 2005), have converged on the conclusion that in many cases the representation or judgement of objects and values is relative in nature. For example, although word recognition models have commonly assumed that letter information is encoded in an absolute, position specific way (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; McClelland & Rumelhart, 1981), recent evidence on letter confusions in briefly presented letter strings shows that transpositions of letters from different positions within words are more frequent than expected from absolute models, implying relativity in the way letters within words are represented (Davis & Bowers, 2004). In a similar vein, a striking phenomenon from a number of domains is that of the range effect, whereby participants' judgements of the physical properties of objects such as lightness (e.g., Bressan, 2006), length (e.g., Lacouture, 1997), and sweetness (Lawless, Horne, & Spiers, 2000) are shifted according to the range of stimuli to which the observer has been exposed.

One common assumption is that participants use some form of anchoring, whereby the representations or judgements of stimuli are anchored to landmarks including the extreme stimuli presented in an experiment (e.g. Braida et al., 1984; Brown, Marley, Donkin, & Heathcote, 2008). In this paper, we consider whether a similar principle of anchoring is at play in short-term order memory. Specifically, we ask to what extent the coding of position of items or events in a sequence is anchored to both the start and end of that sequence (Henson, 1998b; Houghton, 1990). As we discuss below, this issue is of particular significance given one idiosyncratic characteristic of temporal order: the length of a sequence may often be unknown until the entire sequence has been presented, meaning that the end anchor is not usable as a stable referent during encoding. Below, we discuss a number of models of positional representation in short-term order memory, and present a series of simulations and experiments addressing the role of anchoring in short-term order memory.

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Varieties of positional representations in short-term memory

A major focus of models of short-term memory has been the representations or mechanisms by which the order of sequences is remembered. One class of models, primacy models, assumes that items are represented by a gradient in the strength of activations or associations across a sequence, such that earlier items are more accessible (Farrell & Lewandowsky, 2002; Page & Norris, 1998). This simple ordinal scheme has been demonstrated to be sufficient to account for a number of benchmark data from the serial recall task, including serial position effects in accuracy and latency, the locality in positional confusions (nearby items tend to be confused), list length effects, and other phenomenon such as modality and word frequency effects (Farrell & Lewandowsky, 2002, 2004; Page & Norris, 1998). However, there exist data which are incompatible with the basic gradient-based representation assumed in these models.

One major objection to primacy models comes from the multifarious effects of grouping on serial recall performance. Grouping a list into subsequences by inserting pauses between groups (e.g., Maybery, Parmentier, & Jones, 2002; Ryan, 1969a, 1969b), intonation (Frankish, 1995; Reeves, Schmauder, & Morris, 2000), or simply suggesting a grouping structure through verbal instructions (Farrell, 2008; Wickelgren, 1964) lead to a number of well-replicated effects on recall. When examining accuracy, grouping leads to the appearance of "mini" serial position curves for groups, each group with its own primacy and recency. Grouping also has systematic effects on recall latencies: participants leave longer pauses in their output at group boundaries (Farrell, 2008; Maybery et al., 2002). Most problematic for primacy models is the effects of grouping on recall errors, particularly those involving confusions of items between groups (Henson, 1996). When adjacent positional confusions are examined, confusions between groups tend to dominate for ungrouped lists, while confusions within groups dominate for grouped lists (e.g., Maybery et al., 2002). More tellingly, grouping lists increases the tendency of participants to produce interpositions: if an item is recalled in the incorrect group, it nevertheless tends to be recalled at the correct-within group position. For example, in a 6-item list grouped into two 3-item groups, the 5th item (i.e., the second item in the second group) will, if recalled anywhere in the first three positions, tend to be recalled at the second position (that is, the second position in the first group; e.g., Henson, 1996; Lee & Estes, 1981).

The pattern of data arising from grouping is inconsistent with primacy models because those models predict that primacy will dominate in any confusions between groups (e.g., an anticipation of an item from a later group will always tend to involve the first item from that group). Although it might be argued that positional confusions occur in some other optional mechanism separate from that accounted for with a primacy gradient (Page & Henson, 2001; Page & Norris, 1998), this weakens these models as universal models of short-term order memory. Alternatively, these data have been taken to indicate a role for positional representations in short-term memory. A number of models assume that the order of items is stored by associating each item with a positional marker specifying the position of the item. By assuming that positional markers for nearby positions overlap, models incorporating positional representations are able to account for a large range of serial recall data (Anderson & Matessa, 1997; Brown, Neath, & Chater, 2007; Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1999; Henson, 1998b; Lewandowsky & Farrell, 2008b). In particular, these models can account for the interpositions seen in grouped lists by assuming representations for both the position of items in a group, and a coarser representation of the items position in the list as a whole (item-in-list: Brown et al., 2000; Burgess & Hitch, 1999) or the position of the group in the list (group-in-list: Anderson & Matessa, 1997; Henson, 1998b; Lewandowsky & Farrell, 2008b). These hierarchical representations are of apparent generality, as participants may spontaneously group lists even when those lists are presented as homogeneous structures (e.g., Madigan, 1980).

Although phenomena such as grouping effects do seem to mandate some positional representations, it could be argued that incorporating such representations shifts the burden of explanation for ordering in the first place. In other words, if ordering is not a property of the items but of some external mechanism, how is that mechanism itself able to correctly order and retrieve its positional representations? The most basic answer to this question is found in models such as that proposed by Conrad (1965), who suggested that items in a sequence are stored in ordered bins in memory. Contemporary models have replaced this scheme with more detailed specifications of the generation of positional representations and their functional relationship across positions (Brown et al., 2000; Burgess & Hitch, 1999; Henson, 1998b). For example, an appealing mechanism for the generation of positional representations is found in the oscillator-based model of Brown et al. (2000), which assumes that a bank of time-varying sinusoidal oscillators generates a temporal context signal that is used to distinguish elements of a sequence and support ordered recall. In the case of grouped lists, an additional bank of oscillators is assumed to be used to code within-group position (see also Burgess & Hitch, 1999; Hitch, Burgess, Towse, & Culpin, 1996). These models, whether they specify the positional representations as varying over time (Brown et al., 2000) or position (Burgess & Hitch, 2006; Lewandowsky & Farrell, 2008b) can generally be classified as absolute models (Henson, 1999a) or *start-anchor* models: items are represented by their position (or time) since the beginning of a group or list.[1]

This representational scheme can be contrasted with a relative coding scheme, in which items are anchored to both the start and the end of a sequence or subsequence (cf. Braida et al., 1984). The clearest demonstration of this scheme has been in the Start-End Model (SEM) of Henson

[1] Henson (1999a) also discusses the possibility of having all items represented by their absolute position with respect to the end of a group or list. Since no contemporary models make this assumption it is not discussed here.

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