CHAPTER 4

Numerical order and quantity processing in number comparison

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Abstract

We investigated processing of numerical order information and its relation to mechanisms of numerical quantity processing. In two experiments, performance on a quantity-comparison task (e.g. 2 5; which is larger?) was compared with performance on a relative-order judgment task (e.g. 2 5; ascending or descending order?). The comparison task consistently produced the standard distance effect (faster judgments for far relative to close number pairs), but the distance effect was smaller for ascending (e.g. 2 5) compared to descending pairs (e.g. 5 2). The order task produced a pair-order effect (faster judgments for ascending pairs) and a reverse distance effect for consecutive pairs in ascending order. The reverse effect implies an order-specific process, such as serial search or direct recognition of order for successive numbers. Thus, numerical quantity and order judgments recruited different cognitive mechanisms. Nonetheless, the reduced distance effect for ascending pairs in the quantity task implies involvement of order-related processes in magnitude comparison. Accordingly, distance effects in the quantity-comparison task are not necessarily a process-pure measure of magnitude representation.

1. Introduction

Comparative judgment tasks have been extensively used to investigate the internal representation and processing of symbolic magnitudes (see Leth-Steensen & Marley, 2000, for a recent review). In these tasks, people judge which of two stimuli (e.g. numbers) is the larger (or smaller) along a continuous magnitude dimension. One of the classic findings reported in symbolic comparison studies is the distance effect, which refers to the decrease in response times as the difference between the stimuli to be compared increases (e.g. Moyer & Landauer, 1967).

With respect to comparative judgments about numbers, the distance effect has been interpreted as evidence that numerals activate a magnitude representation analogous to a compressed number line (e.g. Dehaene, 1989, 1992). Numbers farther apart on the internal magnitude representation are easier to discriminate, giving rise to the distance effect (see Verguts & Fias, 2004; Zorzi, Stoianov, & Umiltà, 2004 for alternative models of magnitude representation and processing). However, numbers convey both quantity (e.g. three runners) and order information (e.g. the third runner) (Butterworth, 1999; Fuson, 1988; Wiese, 2003); consequently, numerical size judgments could be influenced by cognitive processes associated with numerical order (e.g. the verbal counting series). Indeed, the distance effect is also observed with non-quantitative ordered series (e.g. the letters of the alphabet; Jou & Aldridge, 1999). This suggests that the distance effect in numerical comparisons could also be mediated by order information (Wiese, 2003; see also Tzelgov & Ganor-Stern, 2004), and the potential role of order-related processing in number comparison remains an open question (Fias & Fischer, 2004). This question is theoretically important because precise characteristics of distance effects in quantity judgements are crucial to evaluating alternative models of numerical magnitude representation and processing (cf. Zorzi et al., 2004).

Number processing research has focused on the way quantity information is represented, processed and neurally implemented (see Dehaene, Piazza, Pinel, & Cohen, 2003, for a recent review), but we still know relatively little about the way numerical order information is processed (but see Tzelgov & Ganor-Stern, 2004). Studies of order processing with non-numerical sequences may be directly relevant, however (see Leth-Steensen & Marley, 2000, for a recent review). These studies have typically used pairwise judgment tasks in which people were asked either to judge (1) which of two items(e.g. letters) came earlier or later in the (e.g. alphabetic) sequence (analogous to number comparison) (Jou & Aldridge, 1999; Parkman, 1971), or (2) whether a pair of items (e.g. B C) was presented in the conventional (e.g. alphabetic) or non-conventional order(Grenzebach &

McDonald, 1992; Hamilton & Sanford, 1978; Lovelace & Snodgrass,1971). A standard distance effect was found with both paradigms. In the relative-order judgment task, however, two unique effects were also observed. First, pairs presented in the conventional, ascending order were processed faster when adjacent (e.g. B C) than non-adjacent (e.g. B D) in the sequence, thus presenting a reverse distance effect. Second, pair-order affected reaction times (RTs), which were faster for pairs presented in the conventional ascending order (e.g. B C) relative to the descending order (e.g. C B)(Grenzebach & McDonald, 1992; Hamilton & Sanford, 1978; Lovelace & Snodgrass,1971).

These studies therefore suggest the involvement of two qualitatively different cognitive processes in order judgments. The standard distance effect implies a size-based comparison mechanism, similar to that involved in numerical comparison tasks. In contrast, the reverse distance effect for conventionally ordered ascending pairs implies a serial search process in which the time taken to establish the order of two items is determined by the number of items intervening in the sequential series (Jou, 1997). Judgments of numerical order similarly can involve such serial-search processes. Jou (2003) reported a reverse distance effect in a multiple-number comparison task: when participants had to choose the middle number in a three- or five-item array, their RTs were faster for arrays of consecutive numbers (e.g. choosing 5 in 4–5–6) relative to non-consecutive numbers (e.g. 3–5–7). These results raise the possibility that quantity judgments too, under some circumstances, could be mediated by order-related mechanisms (i.e. serial search).

We addressed this issue in two experiments in which we compared performance in a number comparison task and in a relative-order judgment task, on the same number pairs. We examined distance effects to determine whether numerical quantity and order judgments recruited similar or different cognitive mechanisms, and whether potential order-specific processes (e.g. serial search) affected quantity judgments. In Experiment 1, we also included a size-congruity manipulation to investigate whether magnitude information is similarly activated in both quantity and order tasks. The Stroop-like size congruity effect is manifested by longer RTs for incongruent pairs (numerical and physical size disagree; e.g. 5 2), and shorter RTs for congruent pairs (numerical and physical size agree; 5 2), relative to neutral pairs (e.g. 5 2) (e.g. Besner & Coltheart, 1979; Tzelgov, Meyer, & Henik, 1992). This effect is taken as evidence for the automatic activation of numerical magnitude representation (e.g. Henik & Tzelgov, 1982).

2. Experiment 1

2.1. Method

Twenty-four right-handed French-speaking volunteers (mean age 20.2 years) performed two numerical Stroop tasks. In the quantity-comparison task, participants selected the numerically larger (or smaller) number of a pair. In the relative-order judgment task, they judged whether number pairs were in the "correct" (i.e. ascending left to right) or "incorrect" counting order.

For both tasks, stimuli included eight different pairs of Arabic numerals: four close/consecutive pairs (2–3, 3–4, 6–7, 7–8) and four far pairs (2–5, 3–6, 4–7, 5–8). Numerals appeared in two different font sizes (small or large), yielding three congruity conditions: congruent (the numerically larger number is also physically larger), neutral (both stimuli have the same, intermediate, physical size) and incongruent trials (the numerically larger number is the physically smaller). All pairs were presented in both ascending (e.g. 2 3) and descending (e.g. 3 2) order. Unanalysed filler pairs (1–2, 1–4, 6–9, 8–9) ensured that numerals used for the experimental pairs did not anchor the top and bottom of the range of numbers seen. To counterbalance and match the assignment of response-keys, each task was performed twice: once with "choose the smaller" instructions in the quantity task, and "Yes" responses assigned to the left-hand in the order task; once with "choose the larger" instructions and "Yes" responses assigned to the right-hand. Order of tasks (quantity first or order first) was counterbalanced also.[1]

[1] Participants also performed an alphabetic order judgment task (deciding whether letter pairs were presented in the alphabetic order or not). The design was identical to the numerical order task, with each number replaced by its corresponding letter (B for 2, C for 3, and so on). The results replicated previous

Numbers appeared in black on a 145 X 85 mm white frame, at a viewing distance of 50 cm. All numbers were presented in Geneva font, size 64 for small numbers (approximate width by height 14 X 20 mm), size 68 for numbers in neutral trials and size 72 for large numbers (approximate width by height 15.5 X 22 mm). In each trial, a pair of numerals (2.288 apart) appeared at the centre of the screen for 105 ms, followed by a blank screen until a response was given. The next pair appeared 1500 ms after the response.

Each task started with 20 practice trials, followed by 168 experimental trials (144 test trials and 24 fillers) in a pseudo-random order (the same pair never appeared in consecutive trials, the same congruity condition, pair-order or response key were never repeated more than three times). SuperLab Pro (1.74) software was used to display stimuli and record reaction times.

2.2. Results and discussion

Mean of median correct reaction times (RTs) and error rate were computed for each condition. The mean error rate was equivalent in the quantity (4.2%) and order (4.7%) tasks. As mean error rates and mean RTs were positively correlated across cells [$r(22) = .59$, $P < .002$] we present detailed analyses of RT only.

Our initial ANOVA included Task (quantity, order), Distance (1, 3), Congruity (congruent, neutral, incongruent) and Pair-order (ascending, descending) as within-subjects factors and Order of tasks (quantity first, order first) as a between-subjects variable. This omnibus analysis demonstrated that the order in which the tasks were performed (i.e. quantity task first or order task first) entered in a five-way interaction with Task, Distance, Congruity and Pair-order that approached significance, $F(2,44) = 2.68$, $MSE = 1415.61$, $P = .08$. This indicates complex carryover effects from the task performed first that potentially modulated strategies and performance on the second task. Consequently, we focused on the first-task data only, which makes a task between-subjects variable.

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research (e.g. Lovelace Snodgrass, 1971) and are not reported here.

Mean correct RTs for each Task X Distance X Pair-order X Congruity cell appear in Table 1. The source table for the corresponding ANOVA appears in Table 2. All main effects were significant. Mean correct RT was 136 ms faster for the quantity task (590 ms) than the order task (726 ms). This large difference is not surprising given that judging the relative order of two numbers requires not only identifying the smaller (or larger) number, as in the quantity task, but also to process its location (left or right side) in the pair. With respect to overall effects of Distance and Pair-order, far pairs (630 ms) were 35 ms faster on average compared to close pairs (665 ms), and conventional-order pairs (i.e. ascending left to right) were 35 ms faster (630 ms) than descending pairs (665 ms). Size-congruent trials (602 ms) were fast compared to size-neutral trials (640 ms), which were faster than size-incongruent trials (702 ms). The experiment thus produced the standard effects of size congruity, but congruity was not involved in any significant interactions (see Table 2; but see Tzelgov, Yehene, Kotler, & Alon, 2000). The presence of a strong size-congruity effect in both tasks suggests that similar magnitude information was activated in the quantity and order judgments.

Table 1. Mean correct RT (in ms) in the quantity and order tasks in Experiment 1 for each pair-order (ascending, descending) x distance (close, far) x congruity (congruent, neutral, incongruent) condition.

	Quantity task				**Order task**			
	Ascending order		Descending order		Ascending order		Descending order	
Congruity	Close pairs	Far pairs	Close pairs	Far pairs	Close pairs	Far pairs	Close pairs	Far pairs
Congruent	553	529	557	516	635	675	746	694
Neutral	590	566	611	547	675	671	784	726
Incongruent	687	639	678	612	736	758	834	779

Task interacted both with Distance and Pair-order (see Table 2). The Task X Distance interaction occurred because the distance effect for the quantity task was 44 ms (close 612 ms, far568 ms); about twice as large as the overall 18 ms distance effect for the order task (close 735 ms, far 717 ms). Numerical distance therefore had a smaller impact on order judgments than on quantity judgments. Conversely, the Task X Pair-order interaction occurred because there was no overall effect of pair-order for the quantity task (ascending 594 ms, descending

587 ms), whereas there was a 69 ms advantage for the conventional pair-order in the order judgment task (ascending 692 ms, descending 761 ms).Thus, conventional order facilitated order judgments, but had no overall effect on quantity judgments.

Table 2. Four-way analysis of variance of mean correct RT in Experiment 1 with task (quantity, order) as a between-subjects factor and distance (close, far), pair-order (ascending, descending) and congruity (size congruent, neutral, incongruent) as within-subjects variables.

Source	**df**	**F**
		Between subjects
Task (T)	1	9.71**
MSE	22	(136871.64)
		Within subjects: Distance
Distance (D)	1	56.49***
T x D	1	10.71**
MSE	22	(1215.10)
		Within subjects: Pair-order
Pair-order (P)	1	19.77***
T x P	1	30.21***
MSE	22	(3469.39)
		Within subjects: Congruity
Congruity (C)	2	138.75***
T x C	2	2.09
MSE	44	(2288.82)
		Within subjects: Distance x Pair-order
D x P	1	15.80***
T x D x P	1	3.92a
MSE	22	(2816.14)
		Within subjects: Distance x Congruity
D x C	2	2.47
T x D x C	2	1.03
MSE	44	(1291.27)
		Within subjects: Pair-order x Congruity
P x C	2	1.71
T x P x C	2	0.12
MSE	44	(1840.74)
		Within subjects: Distance x Pair-order x Congruity
D x P x C	2	0.70
T x D x P x C	2	0.90
MSE	44	(1576.06)

Note. Values enclosed in parentheses represent mean square. *p < 0.05; **p < 0.01; ***p < .001.

[a] $p = 0.060$

These two, two-way interactions, as well as the Distance X Pair-order interaction, were qualified, however, by evidence of a three-way interaction among Task, Distance, and Pair-order (P=.06)[2], which is depicted in Figure 1. As Figure 1 shows, the quantity group produced the standard distance effect (i.e. slower RTs for close than far pairs) both for ascending and descending pair-order, but the distance effect for ascending (32 ms) was smaller than for descending pairs (57 ms) [F(1,11) = 6.28, MSE = 890.98, P = .03 for the Quantity group's Distance X Pair-order effect]. In contrast, for the order group, descending pairs produced a standard distance effect of 55 ms, but, as we anticipated, for ascending pairs there was a reverse distance effect of K20 ms [F(1,11) = 10.53, MSE = 4741.3, P = .008 for the Order group's Distance X Pair-order effect] that approached significance by a one-tailed test [t(11) = 1.67, P = .06]. Separate analyses of ascending and descending conditions confirmed the Task X Distance interaction for ascending pairs [F(1,22) = 11.19, MSE = 2147.28, P < .003], whereas the distance effect was equivalent when processing either quantity or order for descending pairs (F < 1). Hence, the evidence of a reverse distance effect for conventionally ordered pairs in order judgments suggests that these might be mediated by the counting sequence.

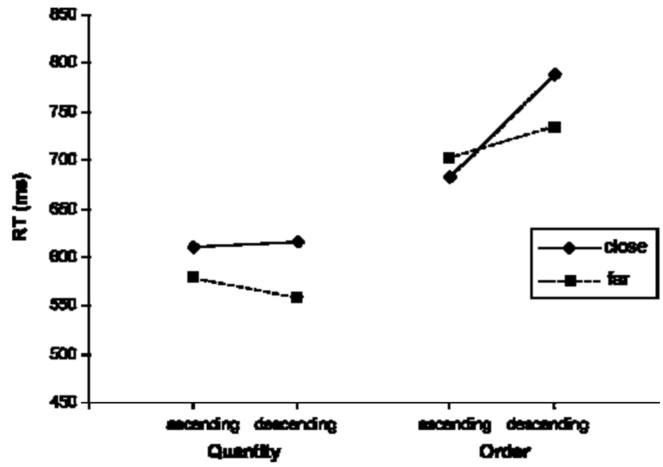

Figure 1. Mean correct RT by task (quantity, order), distance (close, far), and pair-order (ascending, descending) in Experiment 1.

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[2] The Distance X Pair-order interaction, as well as the crucial three-way interaction among Task, Distance, and Pair-order were significant in the ANOVA that included task-order as a factor (i.e. including Task as a within-subjects variable): F(1,22) = 29.34, MSE = 2050.83, P < .0001 and F(1,22) = 5.80, MSE = 2116.44, P < .025, respectively.

3. Experiment 2

In Experiment 2, we further tested the hypothesis that numerical order judgments could be based on a serial search mechanism. Because of the potential importance of the reverse distance effect, this was investigated in more detail by examining pair-distances of 1–4.

3.1. Method

Forty-eight French-speaking volunteers (six left-handed; mean age 24.2 years) performed either the quantity or the order task (24 subjects in each group). Both tasks were identical to those of Experiment 1, with two exceptions: (1) pair-distances of 2 and 4 were also included in the experiment, and (2) all numbers had the same physical size because size congruity did not differentially affect quantity and order processing in Experiment 1.

The same 15 pairs of Arabic numerals were presented in each task: eight pairs for Distances 1 and 3, that were the same as in Experiment 1, four pairs for Distance 2 (2–4, 3–5, 5–7, 6–8) and three pairs for Distance 4 (2–6, 3–7, 4–8). Individual pairs were presented three times each for Distances 1, 2 and 3, and four times each for Distance 4, so that the overall number of pairs to be processed was the same for all distances. All pairs were presented in both ascending and descending order. Unanalysed filler pairs were also included (1–2, 1–3, 1–4, 1–5, 5–9, 6–9, 7–9, 8–9). Stimulus presentation and design were the same as in Experiment 1, with the exception that all numbers had the same, intermediate, physical size (Geneva font, size 68).

3.2. Results and discussion

The mean error rate was larger in the order (5%) than in the quantity task (2.2%) [$t(47) = K3.58$, $P < .001$]. As mean error rates and mean RTs were positively correlated across cells [$r(14) = .73$, $P < .001$] we present detailed analyses of RT only.

Mean of median correct RTs received a repeated-measures ANOVA with Distance (1–4) and Pair-order (ascending, descending) as within-subjects factors and Task (quantity, order) as a between-subjects variable. The mean RTs appear in Figure 2 and the source table for the ANOVA appears in Table 3. All main effects were significant and replicated those of Experiment 1. Specifically, mean correct RT was 172 ms faster for the quantity task (485 ms) than the order task (657 ms). Consecutive pairs (Distance 1, 601 ms) were processed slower than all other pairs (Distance 2, 576 ms; Distance 3, 555 ms; Distance 4, 551 ms; all Ps < .002) and conventionally ordered pairs were 32 ms faster (555 ms) than descending pairs (587 ms).

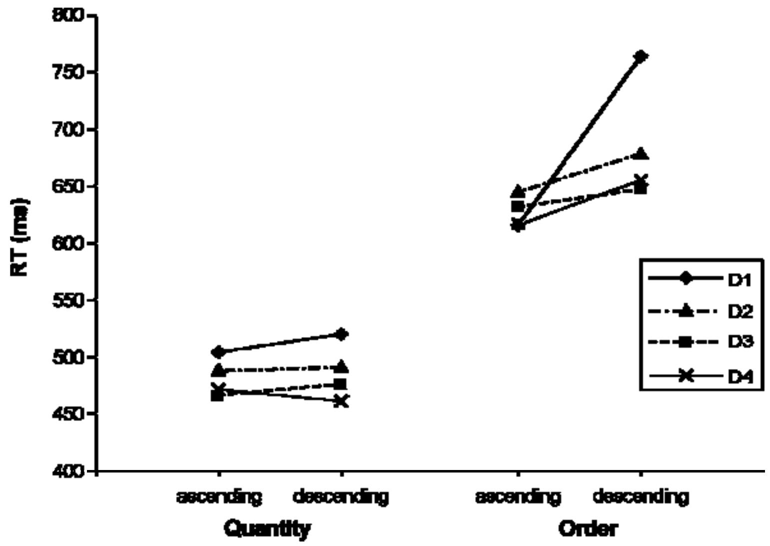

Figure 2. Mean correct RT by task (quantity, order), distance (D1, D2, D3, D4), and pair-order (ascending, descending) in Experiment 2.

Task interacted with Pair-order: as in Experiment 1, there was no overall effect of pair-order in the quantity task (ascending 482 ms; descending 487 ms), whereas there was a 59 ms advantage for the conventional pair-order in the order judgment task (ascending 627 ms, descending 686 ms; $F(1,23) = 42.24$, $MSE = 3931.78$, $P < .0001$). Furthermore, the Task X Pair-order interaction was modulated by pair-distance, producing a triple interaction (see Table 3). To decompose the three-way effect, we performed separate Pair-order X Distance analyses for each task.

Table 3. Three-way analysis of variance of mean correct RT in Experiment 2 with task (quantity, order) as a between-subjects factor and distance (1, 2, 3, 4) and pair-order (ascending, descending) as within-subjects variables.

Source	df	F
		Between subjects
Task (T)	1	54.93***
MSE	46	(51665.99)
		Within subjects: Distance
Distance (D)	3	34.36***
T x D	3	0.27
MSE	138	(2170.96)
		Within subjects: Pair-order
Pair-order (P)	1	42.41***
T x P	1	30.13***
MSE	46	(2305.84)
		Within subjects: Distance x Pair-order
D x P	3	26.19***
T x D x P	3	17.32***
MSE	138	(1041.07)

Note. Values enclosed in parentheses represent mean square. *p < 0.05; **p < 0.01; ***p < .001.

For the quantity-task group, there was a Pair-order X Distance interaction [F(3,69) = 4.02, MSE = 1456.90, P = .011], which occurred because the distance effect was smaller for ascending [33 ms for Distances 1–4; F(3,69) = 11.84, MSE = 1005.06, P < .0001] than descending pairs [58 ms; F(3,69) = 27.47, MSE = 870.24, P < .0001]. All distances were significantly different from one another for descending pairs (Distance 1, 520 ms, Distance 2, 492 ms, Distance 3, 476 ms, Distance 4, 462 ms; all Ps < .012). For ascending pairs, there was no significant difference between Distance 1 (504 ms) and Distance 2 (489 ms), nor between Distance 3 (466 ms) and Distance 4 (471 ms), but other distances significantly differed from one another (all Ps < .023). The interaction between Pair-order and Distance was thus largely attributable to processing of consecutive pairs, which were processed faster in conventional order (504 ms) than in descending order (520 ms; t(23) = K2.042, P < .027).

The order task also produced a significant Pair-order X Distance interaction [F(3,69) = 25.5, MSE = 1719.34, P < .0001]. There was a standard distance effect for descending pairs [F(3,69) = 26.70, MSE = 3980.17, P < .0001], with longer RTs for consecutive (764 ms) than more distant pairs (Distance 2, 678 ms, Distance 3, 647 ms, Distance 4, 655 ms; all Ps < .0001). In contrast, for ascending pairs, there was also a main effect of Distance [$F(3,69) = 3.69$, $MSE = 1248.45$, $P < .016$], but consecutive numbers (Distance 1, 615 ms) were processed 30 ms faster on average than pairs with a Distance of 2 (645 ms; one-tailed t(23) = K2.63, P < .008), and 16 ms faster than pairs with a Distance of 3 (631 ms; one-tailed t(23) = K1.52, P < .07), while farthest pairs (Distance 4, 618 ms) were answered equally fast relative to consecutive pairs (see Figure 2).

The results of Experiment 2 replicated and reinforced those of Experiment 1. The quantity distance effect was again modulated by pair-order; specifically, RTs were faster to process consecutive pairs when presented in the ascending relative to the descending order. For order judgments, a reverse distance effect for consecutive pairs in the ascending order was confirmed relative to Distance 2, with some evidence that consecutive pairs were faster than Distance 3, but not Distance 4. In Section 4 we outline two possible explanations for the reverse distance effect observed here.

4. General discussion and conclusion

Because numerical quantity information hierarchically implies order information, either deciding which is the larger (or smaller) of a pair of numerals (e.g. 5 8), or deciding if the pair is in ascending order, could entail identical number processing. For example, the order task could be performed by identifying the smaller (or larger) number, and then determining if its location relative to the other numeral is in the conventional or the reverse order. In this case, we would expect the order and quantity tasks to present equivalent effects of pair distance, because both tasks hypothetically involve the same magnitude comparison process. The present results, however, clearly show that quantity and order judgments recruited distinct cognitive mechanisms, as indicated by task-specific effects of pair-distance, as well as pair-order.

In both Experiments 1 and 2, the quantity task consistently produced the standard distance effect: close pairs were processed slower than far pairs.

This effect is usually explained by a comparison process operating on information retrieved from a continuous magnitude representation (Dehaene, 1992). The closer two numbers are on the continuum, the more their magnitude-related activation overlaps and the longer it takes to discriminate them (see Zorzi et al., 2004, for alternative approaches to the standard distance effect). There was no overall effect of pair-order in the quantity task, but pair-order modulated the standard distance effect, which was smaller for ascending than descending number pairs.

In contrast, the order-judgment task produced a standard distance effect when pairs were presented in descending order, but a distance effect in the reverse direction for consecutive pairs in ascending order. This implies different cognitive processes for the order task depending on pair-order. The standard distance effect for descending pairs suggests a magnitude comparison strategy; thus, a similar cognitive mechanism was recruited for processing quantity and order for descending pairs. Conversely, order judgments on conventionally ordered pairs (i.e. ascending left to right) tended to be faster when numbers were close than farther apart. Two explanations for the reverse distance effect observed here suggest themselves.

Authors have generally accounted for the reverse distance effect in order judgments in terms of a serial search or sequence-recitation strategy (e.g. Jou, 1997, 2003; Lovelace & Snodgrass, 1971). For ascending pairs, this process should generate a monotonic increase in response times with increasing pair distance. This pattern was not observed in the present experiment nor in previous studies of order processing (e.g. Grenzebach & McDonald, 1992; Jou, 2003); instead response times for well-ordered (i.e. ascending) pairs were shown to increase significantly only from Distance 1 (i.e. successive items) to Distance 2. Nonetheless, the results potentially are consistent with a serial search mechanism. It is possible that, for distances greater than 1, magnitude comparison becomes more salient and efficient and supercedes serial search. This might be expected in the number domain because consecutive pairs in the forward counting sequence would have the strongest associations. As distance increases, the efficacy of counting-based performance relative to magnitude-based performance would shift in favor of magnitude comparison (as suggested by the standard distance effect for pair distances of 2–4), and the probability that counting mediates order judgments would decrease. Participants would thus use a mixture of both strategies (serial search and comparison) for order construction, with the adoption of each mode probabilistically determined on each trial according to pair-distance (see also Jou, 1997).

Nonetheless, the restriction of the reverse distance effect to consecutive ascending pairs invites a second interpretation. Well-ordered successive items might have a special status because they are more familiar and more frequently associated in the language than non-successive (but still well-ordered) stimuli. For example, given their familiarity, participants might be able to directly recognize ascending successive pairs, or to use a quick sequence recitation strategy. In contrast, determining the order of non-successive well-ordered items might depend on a different mechanism, possibly comparison, as suggested by the data pattern of Experiment 2 (i.e. a standard distance effect for Distances 2–4).

In summary, the occurrence of a reverse distance effect in the order task for consecutive relative to Distance 2 pairs is consistent with either (1) the hypothesis of a serial search process that is evident at Distance 1 but gradually masked by magnitude comparison processes, or (2) the hypothesis that order judgments are generally based on a magnitude comparison mechanism, but this is superceded in the special case of ascending successive pairs, which are processed through a special mechanism (e.g. direct recognition of order). Overall, order judgments were substantially faster when numbers were conventionally ordered relative to when they were in descending order. This pair-order effect is consistent with order processing studies of non-numerical sequences (e.g. Grenzebach & McDonald, 1992; Lovelace & Snodgrass, 1971). The conventional order apparently allows people to exploit acquired or canonical representations or processes that facilitate performance. For example, faster order judgments for ascending number pairs might be explained by congruity with the forward counting sequence, or that conventionally ordered pairs can be more directly mapped to an internal number line ordered from left to right (Brysbaert, 1995; Dehaene, 1992).

For the quantity task, the smaller distance effect for ascending relative to descending pairs raises the possibility that serial search sometimes mediated quantity judgments. Because serial search trials tend to produce a negative distance effect, they would reduce the standard distance effect in quantity judgments for ascending pairs. Order information may be automatically activated (cf. Gevers, Reynvoet, & Fias, 2003), which would sometimes allow quantity judgments based on serial search to supercede performance based on direct magnitude comparison. This is supported in Experiment 2 by faster quantity judgments of consecutive pairs when presented in the conventional, relative to the non-conventional, order, thus reinforcing the assumption that the reverse distance effect for the order task and the modulated distance effect for the quantity task might reflect the same mechanism. An important implication is that quantity judgments made on pairs of numbers do not necessarily provide a pure measure of magnitude processing, but rather measure a mixture of magnitude and order processing. As current theories of number processing place particular emphasis on accounting for the distribution of RTs (e.g. the standard distance effect) in comparative judgments of numerical magnitudes (see Zorzi et al., 2004), they require precise behavioural indices of magnitude effects. Thus, it is important for researchers to recognize that distance effects in quantity judgments sometimes reflect multiple, counteracting influences.

Finally, the present data suggest that judging quantity or numerical order could involve activation of the same internal magnitude representation, as reflected by a strong size-congruity effect in both tasks and by equivalent distance effects for descending pairs in the two tasks in Experiment 1, but that different processing strategies can ensue depending upon task demands and other mechanisms or information activated by the stimulus.

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