Dual Processes, Development, and Scalar Implicature

Susan Scrafton (susan.scrafton@durham.ac.uk)
Child Development Research Unit, Wolfson Research Institute,
Queen's Campus, Durham University,
Stockton-on-Tees TS17 6BH United Kingdom

Aidan Feeney (aidan.feeney@durham.ac.uk))
Applied Psychology, Queen's Campus, Durham University
Stockton-on-Tees TS17 6BH United Kingdom

Abstract

Dual process theories suggest that our thinking is determined by separate, but interacting, heuristic and analytic processes. We describe an experiment designed to investigate the development of these processes. We examined the extent to which groups of 6, 9, 12, and 15 year-old participants and a group of adults were sensitive to scalar implicature in pragmatically enriched and pragmatically impoverished contexts. For younger participants we find high rates of pragmatic responding in enriched contexts and high rates of logical responding in impoverished contexts. Early adolescents displayed universally pragmatic responding whilst logical responding re-emerged in older adolescents and adults. These results suggest that heuristic processes develop earlier than analytic processes but that they are not well developed until early adolescence.

Keywords: Reasoning, pragmatics, heuristics, context

Introduction

Cognitive development has traditionally been viewed as unidirectional, with the simple, inefficient and intuitive thought processes of childhood gradually replaced by more complex, efficient, systematic and analytical processes. However, this view that simpler processes are supplanted by more complex ones is challenged by dual-process theorists who suggest that different kinds of thinking may interact (see Evans & Over, 2004; Sloman, 1996; 2002; Stanovich, 1999; Stanovich & West, 2000). According to dual-process theories (for recent reviews see Evans, 2003; Osman, 2004) there are two separate but interacting processes for reasoning. Heuristic processes are believed to be fast, parallel, automatic, and unconscious in nature. They are often described as being associative, as they result in pragmatic responding that is often driven by context. Importantly, they are also cognitively undemanding and hence, may emerge relatively early in development. Analytic processes, on the other hand, are conscious, controlled, constrained by working memory capacity and slower than heuristic processes. In addition, they are held to be responsible for decontextualised thinking (Stanovich, 1999), which underlies our ability to reason or decide independently of context. The main aim of this paper will be to consider the developmental trajectory of the two types of process. However, we will first consider the distinction in more detail and review the very limited developmental literature that it has motivated.

Evidence for the existence of two types of thinking comes from a range of sources using a variety of methodologies. One important piece of evidence concerns people's ability to resist background beliefs when engaged in deductive reasoning. In the belief bias paradigm (Evans, Barston & Pollard, 1983) participants are presented with syllogisms where the validity of the conclusions and the believability of the premises have been crossed in a fully factorial design. Although people tend to accept more valid than invalid conclusions, they also tend to accept more conclusions that are believable than unbelievable. This finding is taken as evidence for the co-existence of belief-based heuristic processes, and separate analytic processes capable of decontextualising the information in the problem.

Further studies of belief bias have shown that it is more common in older people (Gilinsky & Judd, 1994) and under conditions of speeded response (Evans & Curtis-Holmes, 2005). The tendency to respond in accord with logical validity on the belief bias task is also known to be associated with IQ (Stanovich & West, 1998). These findings support the claim that there are separate processes for reasoning, one of which is fast, computationally inexpensive and context-driven, whilst the other is slow, computationally expensive, heavily dependent on working memory and responsible for dexcontextualising the problem. Furthermore, neuropsychological studies have shown a within-subject anatomical disassociation between areas associated with belief-based responding and those associated with logical responding (Goel & Dolan, 2004).

Developmental Evidence

Dual process theories are based, by and large, on adult data and have not been widely applied to reasoning in children and adolescents. A notable exception is Klaczynski's work on adolescent thinking (Klaczynski, 2001; Klaczynski & Cottrell, 2004). Klaczynski (2001) examined the gap between young and middle adolescents' performance on reasoning tasks and traditional standards of reasoning. He showed that rather than being random errors, non-normative responses were positively correlated, normative responses were positively correlated, and the two forms of response

were largely independent of each other. Support for a two-process model came from both factor analysis, which revealed that the two types of response did not load onto the same factor, and the finding that normative analytical responding was positively correlated with IQ. Finally, he found that normative responding was more likely in middle than in early adolescence whereas non-normative responding was not associated with age. These findings can be interpreted as evidence for the existence of one type of thinking that is well developed by early adolescence and another which continues to develop between the ages of 12 and 15.

Other relevant evidence has been described by Handley, Capon, Beveridge, Denis and Evans (2004) who investigated the degree to which logical responding by 10-year-olds in a belief bias task is predicted by working memory capacity and the ability to inhibit prepotent responses. Handley et al. (2004) discovered that each of these individual differences variables is a significant and independent predictor of the tendency to respond logically. The findings suggest that analytic thinking, essential for logical responding, requires working memory resources and that heuristic and analytic processes may operate in parallel. Handley et al. (2004) suggest that responses based on faster heuristic processing dominate unless inhibited by the information processor in favour of a response based on slower analytic processes.

The picture that emerges from these investigations is of dual processes that are present in some form by 10 years-of-age. Whereas there is no evidence that pragmatic or heuristic processes are not fully developed by that age, there is evidence that analytic processes are still developing at the age of 15. However, one dissatisfying aspect of the studies that we have described is that the full age range has not been investigated. Had it been so, it might have been possible, not only to demonstrate the emergence of analytic processes, but also to investigate the development of heuristic processes, and so to trace the relationship in development between the two types of thinking.

Scalar Implicature and Dual Processes

One problem with designing a truly developmental study is finding a reasoning task equally as suitable for young children as for adults. Klaczynski (2001) was able to highlight the relationship between normative and non-normative responding because he chose tasks where the out puts of the two systems were in accordance or in conflict with each other. However, many of the tasks he used are unsuitable for use with young children. Below, we describe an experiment designed to investigate the development of sensitivity to scalar implicature, a particular kind of conversational inference, in participants aged from five years up to adulthood. We chose to examine scalar implicature because it lends itself to a developmental approach and because scalar terms appear to place the two systems for reasoning in conflict.

A scalar inference or scalar implicature (SI) is the assumption made by the hearer that the speaker's use of a weaker term implicates that the stronger term does not hold. Consider the use of the word *some* in the following sentence:

(1) Some of the students attended the lecture.

According to Grice's (1989) maxims of conversation, if it is known that a strong term such as *all* is the case then the speaker should use the stronger term. As it is not used in this case, sentence 1 will often be interpreted as:

(2) Some but not all of the students attended the lecture

However, logically *some* is an existential quantifier asserting that there is at least one. Consequently it is compatible with *all*, as *at least one* does not preclude *all* and so the sentence could be interpreted as:

(3*) Some and maybe all* of the students attended the lecture.

In the reasoning literature it has long been known that adults frequently interpret *some* pragmatically (Ceraso & Provitera 1971; Begg & Harris, 1982) rather than logically.

There has been a resurgence of interest in the interpretation of scalar terms with Noveck's (2001) findings that young children appeared not to derive SIs and so appeared to be more logical than adults. He discovered that 8 and 10 year old children were more likely to agree with the statement "*Some* elephants have trunks", than adults, with logical response rates of 89%, 85% and 41% respectively. However, the children were generally very good at detecting the inappropriateness of other statements that were not pragmatically infelicitous. For example, they correctly agreed with the statement "*Some* birds live in cages" and correctly disagreed with "*All* dogs have spots". Accordingly, Noveck concluded that they failed to derive SIs because the pragmatic interpretations were not yet available to them. These results appear to be borne out by other studies looking at the interpretation of *some*, which have also found high rates of pragmatic responding amongst adults (Papafragou & Musolino, 2003; Bott & Noveck, 2004) and high rates of logical responding amongst children (Papafragou & Musolino, 2003; Pouscoulous & Noveck, 2004).

However, there is evidence to suggest that children are not always insensitive to the implicature associated with *some*, and can give pragmatic interpretations if there is a change in context (Feeney, Scrafton Duckworth & Handley, 2004; Papafragou & Tantalou, 2004), or in task demands (Papafragou & Musolino, 2003). For example, Feeney et al. (Expt. 2, 2004) presented 8-year-olds with relatively impoverished materials, such as those used by Noveck (2001), and with pragmatically enriched storyboards in which a girl was seen, for example, to eat three biscuits. When asked by her mother what she had been doing, the girl

replied that she had eaten *some* of the biscuits. Children tended to accept Noveck's statements (57% logical response rate), but rejected the girl's statement (21% logical response rate), thus demonstrating selective sensitivity to the scalar implicature.

Explanations for this pattern of findings can be offered in terms of dual processes for reasoning. For example, one interpretation of the finding that children answer pragmatically in one context but logically in another is that at age eight, the ability to reason using heuristic processes is still developing. For Noveck's materials, children may respond logically to "*Some* giraffes have long necks" because they are unable to employ the relevant pragmatic heuristic either through the lack of contextual clues or a lack of experience (or because there is no incentive to invest more cognitive resources to compute the implicature). In the Feeney et al. (2004) enriched task the context readily supports the pragmatic interpretation. The laws of conversation say that the girl should use the strongest term possible to describe her actions; to do otherwise suggests an intention to deceive. Supported by the pragmatics of the context children give pragmatic responses. The fact that they do not make a logical interpretation even though they were able to do so in the statements task, suggests that their logical responses are not due to the use of analytic processes for decontextualised reasoning. However, adults who respond logically on Noveck's materials may do so in spite of the availability of the pragmatic interpretation. Because their analytic processes are more fully developed, they are more likely to be able to resist the effects of conversational context, decontextualise the problem, and respond logically.

Unfortunately, we do not have adolescent data for either of the tasks used in Feeney et al. (2004) or adult data for the enriched task. Such data might be very informative with respect to the developmental relationship between the two types of thinking. For example, previous work suggests that heuristic processes are developed before analytic processes (Klaczynski, 2001). Accordingly, there may be a point in adolescence, when heuristic processes are well developed and analytic processes are still developing, at which children are wholly pragmatic in their responses. As Feeney et al. (2004) found evidence that logical responding is also common in adults, it is possible that adolescents at this point in development may be even more pragmatic than adults.

Experiment

In this experiment we will compare the sensitivity of groups of 6, 9, 12, and 15 year-old participants, as well as a group of adults, to the scalar implicature associated with *some*. We derived three predictions from dual-process theory. First, the effect of context should be seen at an early age. If the performance of the 8 year-old children in the Feeney et al. (2004) study is due to partly developed heuristic processes, then we may observe sensitivity to the implicature in some contexts but not in others. Second, if heuristic processes develop before analytic processes there should be an age at which pragmatic responding will be the norm regardless of

context. Third, because logical responding re-emerges in adulthood, as the ability to process problems analytically develops we might expect to observe that adults give fewer pragmatic responses than the highly pragmatic adolescents. In addition to these predictions, if dual process theory is correct, we would not expect to see more logical responding in the enriched condition for any of the age groups.

Method

Participants
One hundred and nine people participated in the experiment. These were split into five age groups: 24 Year 1 children, age range 5 years 9 months to 6 years 9 months; 23 Year 4 children, age range 8 years 9 months to 9 years 9 months; 22 Year 7 children, age range 11 years 10 months to 12 years 10 months; 21 Year 10 children, age range 14 years 10 months to 15 years 10 months; and 19 adult participants. The Year 1, Year 4, and Year 7 groups were recruited from two schools in the North East of England. The Year 10 group was recruited from a local school and a youth group. The adult participants were recruited at Durham University.

Materials
Participants heard a list of 24 statements and saw a series of 16 storyboards.

Impoverished Materials: These materials are based on the statements used by Noveck (2001), and concern three types of information; factually universal, factually existential and absurd. A factually universal statement is one where the quantifier *all* best describes how many of a group possess a particular feature, such as *all* elephants have trunks. A factually existential statement is one where the quantifier *some* best describes how many of a group possess a particular feature, such as *some* animals have stripes, whilst an absurd statement is one where neither quantifier correctly describes it, such as garages sing. The statements used describe a relation between the quantifier and the noun and can be broken down into subgroups, which can be seen in Table 1, along with an example for each context. Each statement was presented with either *all* or *some* preceding it, although each participant received only one form, which resulted in two sets of materials. The statements within each set were randomly ordered.

Enriched Materials: The 16 storyboards are taken directly from Feeney et al. (2004). Each of the storyboards contained four or five coloured photographs, depending on the condition, and depicted a theme. There were 16 themes each of which concerned the activities of a girl in relation to a set of objects she finds, such as eating sweets or picking flowers. In each storyboard the girl was seen finding three objects and interacting with either two or three of them. In each case she was asked, by her mother, what she has done to the objects. She replied by stating that she has interacted with *all/some* of them, such as, "I've eaten *all/some* of the

biscuits".Participants saw each theme in one of the four forms, which were systematically allocated amongst the four subgroups. Two sets of materials were prepared. There were two pairings of statements and storyboard materials and the order of presentation was counterbalanced.

Table 1: The different truth/quantifier subgroups with an example from each context

Sub Group	Impoverished (Sentences)	Enriched (Storyboards)
True/ All	All elephants have trunks	I ate all the biscuits (ate 3/3 biscuits)
False/ All	All dogs have spots	I dirtied all the towels (dirtied 2/3 towels)
Absurd/ All	All garages sing	
True/ Some	Some animals have stripes	I broke some of the tiles (broke 2/3 tiles)
Infelicitous/ Some	Some giraffes have long necks	I picked some of the flowers (picked 3/3 flowers)
Absurd/ Some	Some policemen are made of jelly	

Note. The enriched condition contained no absurd subgroup

Procedure

Participants received instructions on how to complete each task immediately before they attempted that task. For the impoverished task, participants were told that they would hear a series of statements and they had to decide whether each was true or false. For the enriched task, participants were told that they would see a number of storyboards and hear accompanying text. Their task was to decide whether the response made by the child was true or false. For both tasks the participant had an answer sheet on which to record their decisions.

Results

The participants' responses were coded with respect to their logical correctness. The correct logical response for the true/felicitous *all* categories is true whilst the correct logical response for the false /infelicitous *all* categories is false. However for *some* the correct logical response is always true, regardless of truth or felicity.

Before the data was analysed the scores of 2 year 1 children, 4 Year 10 children and 2 adults who scored at or below chance levels in one of the true *all* categories were removed. The mean scores and standard deviations for the remaining participants broken down by truth, term and condition can be seen in Table 2.

Collapsing results on the impoverished task across age group, fewer logical responses were given to the *some*

statements than to the *all* statements, Wilcoxon matched pairs signed ranks test $z = 7.17$, $T = 63$, $p < .001$, and to the false/infelicitous statements than to the true statements, Wilcoxon matched pairs signed ranks test $z = 7.05$, $T = 113.5$, $p < .001$. Turning now to the infelicitous *some* statements, a Mann Whitney test reveals that the Year 1 children gave significantly more logical responses than the Year 4 children, $U = 93.5$, $p < .001$, the Year 4 Children gave significantly more logical responses than the Year 7 children, $U = 115.5$, $p < .001$, and the Year 7 children gave significantly fewer logical responses than either the Year 10 children, $U = 107$, $p < .005$, or the adults, $U = 56.5$, $p < .001$ There was no significant difference in the number of logical responses given by these last two age groups, $U = 105.5$, $p = .164$.

Table 2: Mean number of logical responses (and standard deviations) for quantifier terms broken down by context and age

Truth/ Felicity	Context	All				
		Yr 1	Yr 4	Yr 7	Yr 10	Adult
True/ Felicitous	Enrich	3.95	3.86	4.00	3.88	3.82
		(0.21)	(0.35)	(0.00)	(0.33)	(0.39)
	Impov	3.91	4.00	3.86	3.76	3.88
		(0.29)	(0.00)	(0.35)	(0.44)	(0.33)
False/ Infelicitous	Enrich	3.73	3.95	3.91	3.94	3.59
		(0.63)	(0.21)	(0.29)	(0.24)	(1.00)
	Impov	3.91	3.91	4.00	4.00	3.94
		(0.29)	(0.29)	(0.00)	(0.00)	(0.24)
		Some				
		Yr 1	Yr 4	Yr 7	Yr 10	Adult
True/ Felicitous	Enrich	3.59	3.68	4.00	3.94	3.94
		(0.50)	(0.48)	(0.00)	(0.24)	(0.24)
	Impov	3.73	3.95	3.95	4.00	4.00
		(0.46)	(0.21)	(0.21)	(0.00)	(0.00)
False/ Infelicitous	Enrich	0.95	0.27	0.14	1.35	1.35
		(1.36)	(0.55)	(0.35)	(1.84)	(1.62)
	Impov	3.95	1.95	0.18	1.35	2.18
		(0.21)	(1.84)	(0.50)	(1.66)	(1.63)

Note: The maximum number of correct logical responses for each statement type was four.

Collapsing across age group on the enriched task, fewer logical responses were given to the *some* storyboards than to the *all* storyboards, Wilcoxon matched pairs signed ranks test $z = 8.32$, $T = 62.5$, $p < .001$, and to the false/infelicitous storyboards than to the true storyboards, Wilcoxon matched pairs signed ranks test $z = 8.51$, $T = 2.5$, $p < .001$. For the infelicitous *some* materials, there was a significant

difference in the number of logical responses made between the age groups, Kruskal-Wallis test, H (4) = 11.8, p < .02. The Year 7 children made significantly fewer logical responses than the Year 10 children, Mann Whitney test U = 126.5, p < .025, but there was no significant difference in logical responding between the Year 10 children and the adults, Mann Whitney test U = 138.5, p = 0.82.

Once again collapsing across age groups, fewer logical responses were made to infelicitous *some* in the storyboard condition than in the statement condition, Wilcoxon matched pairs signed ranks test z = 5.01, T = 98, p < .001. The effect of context for each age group can be seen in Figure 1. Fewer logical responses were made in the storyboard condition by the Year 1 children, Wilcoxon matched pairs signed ranks test z = 4.05, T = 0, p < .001, and by the Year 4 children, z = 3.23, T = 1.5, p < .002, but there was no significant effect of context for the other age groups, p > .05.
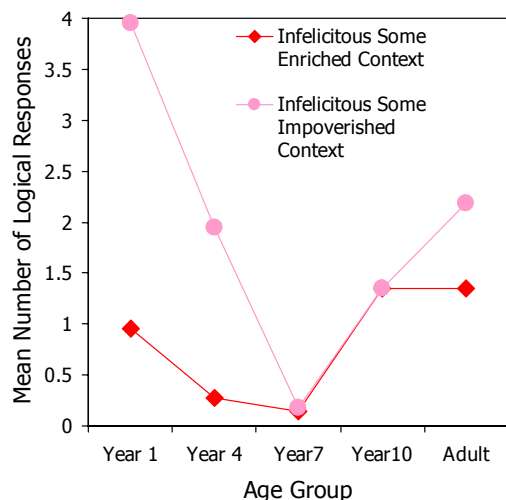

Figure 1. Mean number of logical responses to infelicitous *some* for each age group according to context.

Discussion

At the outset we predicted: (1) an effect of context in young children; (2) that in early adolescents pragmatic responding would be the norm regardless of context; and (3) that adults would give fewer pragmatic responses than the highly pragmatic adolescents. The results of this experiment have confirmed all three of these predictions. Thus, sensitivity to the implicature associated with *some* is dependent on age, and for some ages, on the context in which the scalar term appears. In addition, no age group had higher logical response rates in the enriched than in the impoverished condition.

The Year 1 children were able to spontaneously detect the implicature but only if the context was supportive, as in the case of the pragmatically enriched storyboards. The Year 4 children were also greatly influenced by the context in which the scalar term appeared and were more likely to respond pragmatically in the enriched rather than in the

impoverished condition. However, from this age onwards the children could also detect the implicature in the statements at a rate equal to or greater than that of the adults, to the extent that the Year 7 children were universally sensitive to the implicature regardless of context. After Year 7 the participants remained largely insensitive to the effect of context but rates of logical responding increased.

So can these findings be accounted for by a dual-process theory of reasoning, and if so how might these processes develop?

There is certainly evidence of pragmatic responding in adults. Although their logical responses are close to ceiling on the other categories, the amount of pragmatic responding on infelicitous *some* suggests that a pragmatic heuristic has been activated. The fact that the adults are not influenced by context suggests that this heuristic is well developed in that it is activated in contexts that facilitate logical responding in children.[1] This lack of effect of context also suggests that those participants who gave predominantly logical responses (see Table 3 for individual patterns of responding for each age group) did so because they had decontextualised the task.

Table 3. Types of responder broken down by age group

Response[a]	Age Group				
	Year 1	Year 4	Year 7	Year 10	Adult
	(n=22)	(n=22)	(n=22)	(n=17)	(n=17)
Log/Log	5			4	4
Prag/Prag		10	21	10	6
Prag/Log	16	9			4
Neut/Log	1	1			1
Prag/Neut		2	1	1	1
Log/Neut				1	
Log/Prag					1
Neut/Prag				1	

Note. Log = logical responder ≥ 3 correct responses; Prag = pragmatic responder ≤ 1 correct response; Neut = neutral responder = 2 correct responses.
[a]In the response category the pairings show the enriched context followed by the impoverished context.

In the early adolescent group (Year 7), the total predominance of pragmatic responding regardless of context suggests that by this age the heuristic system is well developed but that the analytic system is, at best, still developing. By middle adolescence, however, logical responding has re-emerged and where it occurs, it appears to be the result of thought processes operating on decontextualised representations. The finding that adolescents who give the logical response do so across both contexts supports this conclusion.

The reasoning processes of the youngest participants appear to rely mainly on context. Although the children can respond pragmatically they can only do so in the

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[1] If the materials had been designed solely for adults they could have been more complex and might have produced an interaction with context.

pragmatically enriched context. The complete absence of predominantly pragmatic responders (see Table 3) suggests that the heuristic system is not well developed or easily activated. This lack of development is also suggested by a small group of predominantly logical responders. Their responses are unlikely to be due to the same processes as those of the predominantly logical responders in the Year 10 and adult groups as there is a complete absence of this type of responder in Years 4 and 7. It is more likely that this group of Year 1 children have failed to activate a pragmatic heuristic than that they have engaged in analytical thought. Similarly, the logical responses that are evident in the Year 4 children are only found in the impoverished condition. If these children were true logical responders then one would expect to see some evidence of decontextualisation and logical responding in the enriched context.

In conclusion we propose that young children appear to be logical because they do not have a fully developed ability to reason heuristically. In the developing state these processes are effective only if the context supports them. However, as development continues they come to dominate to the extent that pragmatic responding is the norm regardless of context. After this, the operation of more fully developed analytic reasoning processes may be observed in some individuals. This leads to the re-emergence of logical responding, which appears to be the product of analytical thought. In terms of dual processes we have evidence that heuristic processes develop before analytic processes and that heuristic processes are highly sensitive to context whilst they themselves are developing.

Acknowledgments

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