The Hierarchical Transformation of Event Knowledge in Human Cultural Transmission*

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ABSTRACT

There is extensive evidence that adults, children, and some non-human species, represent routine events in the form of hierarchically structured 'action scripts,' and show superior recall and imitation of information at relatively high-levels of this hierarchy. Here we investigate the hypothesis that a 'hierarchical bias' operates in human cultural transmission, acting to impose a hierarchical structure onto descriptions of everyday events, and to increasingly describe those events in terms of higher hierarchical levels. Descriptions of three everyday events (going to a restaurant, getting up and going shopping) expressed entirely in terms of basic low-level actions were transmitted along ten chains each containing four adult human participants. It was found that the proportion of low-level information showed a significant linear decrease with transmission generation, while the proportions of medium- and high-level information showed significant linear increases, consistent with the operation of a hierarchical bias. The findings additionally provide support for script theory in general, and are discussed in relation to hierarchical imitation in non-human primates.

KEYWORDS

Cultural transmission, Hierarchical structure, Event knowledge, Scripts, Schemas.

Cultural transmission is the process by which learned information passes from individual to individual. This is contrasted with the transmission of information genetically, or information acquired through individual learn-

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ing. The earliest experimental investigations into cultural transmission were carried out by Bartlett (1932) using his 'method of serial reproduction,' in which a participant reads some stimulus material, then after a short delay recalls it. This recall is then presented to a second participant to recall, whose output is given to the third participant, and so on along a transmission chain. Bartlett (1932) was thus able to study the changes that occurred to the material as it passed along the chain, and compare the differential degradation rates of different types of material.

One of the key findings of Bartlett's (1932) original studies was that folk tales were transmitted with greater fidelity than any other text, such as a newspaper article, a description of a scene or a scientific argument. Bartlett (1932) argued that folk tales were more amenable to transmission because people possess 'story schemas,' which represent the underlying structure of generic stories such as folk tales, around which the specific details of that particular story may be reconstructed. Cognitive psychologists such as Mandler and Johnson (1977), Rumelhart (1977) and Thorndyke (1977) later expanded this concept of a 'story schema,' characterising its structure as *hierarchical*, drawing on Chomsky's (1957) argument that the grammatical structure of language is organised hierarchically (indeed, some of these were called 'story grammars'). Specifically, folk stories are organised in branching tree-like structures, with the general theme or gist at the highest level of the hierarchy, which branches out into separate events, each of which in turn contain sub-goals, and finally down to the low-level constituent actions that are performed to achieve those sub-goals.[1] Consistent with this theory, Thorndyke (1977) found that stories with such an underlying hierarchical organisation were rated as easier to comprehend and recalled better than stories similar in content but without a hierarchical organisation. Furthermore, the higher a fact was in the hierarchy, the more likely it was to be recalled.

Schank and Abelson (1977) similarly invoked the concept of an underlying hierarchical structure in their script theory. A *script* is defined as

[1]This is, therefore, a *partonomic* hierarchy, based on 'part-of' relations (i.e. each action forms 'part of' a sub-goal, which in turn is 'part of' the gist), rather than a *taxonomic* hierarchy, such as taxonomies of species, which are based on 'kind-of' relations (Zacks and Tversky 2001). Henceforth, discussion of hierarchies concerns partonomies rather than taxonomies.

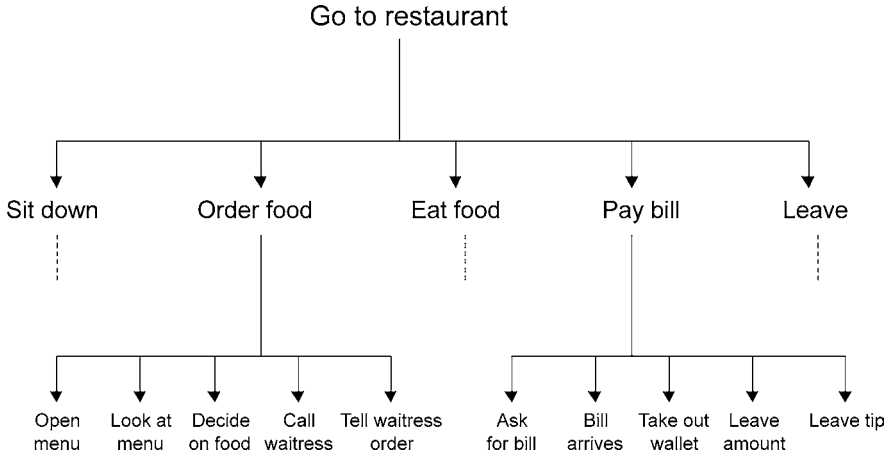

Figure 1. An action script for going to a restaurant. The three levels correspond to the high-, medium- and low-levels used in this study. Not all of the low-level actions are displayed.

a stereotypical knowledge structure for an everyday routine event, such as going to a restaurant or visiting the doctor, around which specific instances of that event are built. For example, going to a restaurant would contain several sub-goals, such as being seated, ordering food, eating, and paying the bill. Each of these in turn contains a series of actions that must be performed in order to achieve the sub-goal. 'Ordering,' for example, contains actions such as reading the menu, deciding what to have, signalling to the waitress and so on. Ultimately, each sub-goal must be completed before the overall goal of eating at a restaurant can be achieved. An example of this hierarchical structure is displayed in Figure 1.

Consistent with script theory, Bower, Black, and Turner (1979) found that when presented with a series of actions forming a script event, participants agreed on how to group those actions into higher level segments. Furthermore, when the usual order of a script was scrambled, participants tended to spontaneously reintroduce the original order, and in subsequent memory recognition tests, participants claimed to have read actions that were not in the original stimulus material but which could be inferred from higher levels of the script. Abbott, Black, and Smith (1985) expanded upon this latter finding by showing that participants falsely inferred the presence of higher level sub-goals (e.g. 'They ordered

their meal') when presented with lower level constituent actions (e.g. 'They discussed what they wanted to eat'), but not vice versa. This asymmetry suggests the existence of a hierarchical organisation with increasing levels of abstraction.

More recently, Zacks, Tversky, and Iyer (2001) found further evidence for the hierarchical structure of scripts using a slightly different methodology. Participants were shown videotapes of models performing routine activities, such as washing the dishes or making the bed, and were asked to segment these activities into either the smallest or the largest meaningful units. It was found that the large unit boundaries were significantly likely also to be small unit boundaries, suggesting an underlying hierarchical structure. This was observed when segmentation was performed both while watching the video (by pressing a key when a segment boundary occurred) and when recalling the video from memory. An important point from this study is that it demonstrates that the hierarchical organisation of script events is not simply an artifact of representing such events linguistically, and so dispels the criticism that the effects described above may simply be a by-product of the hierarchical organisation of linguistic grammar.

That the hierarchical nature of event knowledge is independent of language is reinforced by studies of preverbal children and non-human species. Developmental psychologists have shown that children also possess well organised and stable knowledge about familiar events that resembles action scripts, suggesting that scripts are a fundamental component of cognition. Nelson and Gruendel (1986) interviewed 2 1/2 to 6 year old children for their verbal descriptions of everyday events such as eating lunch, getting dressed and going shopping. It was found firstly that there was general agreement across children on the acts that constituted each event, secondly that these acts resembled the sub-goals of an action script (e.g. sitting down, ordering, eating), and thirdly that these acts were produced more often than more specific low-level actions. Slackman, Hudson, and Fivush (1986) reported that upon further prompting, children readily produced the constituent actions of each sub-goal, indicating an understanding of the lower levels of the hierarchy. Slackman et al. (1986) also reported the use of increasingly more elaborate hierarchical organisation between the ages of 4 to 6 years, with both the number of

elements (e.g. sub-goals and actions), and the children's understanding of how those elements can be placed in the hierarchy (e.g. whether they are necessary or optional, or conditional upon another element), increasing with age and experience. More recently, van den Broek, Lorch, and Thurlow (1996) similarly found that 4 and 6 year olds showed better memory for events at a higher hierarchical level than at a lower level when recalling stories from television programmes.

There is also evidence that a precursor to hierarchical action scripts is present in children under two years of age. Bauer and Mandler (1989) modelled a series of causally related actions resembling a simple script (such as 'remove bear's shirt, put bear in bath, wash bear') for 16 and 20 month olds. When subsequently encouraged to imitate these actions, sequences with causal (or enabling[2]) relations were reproduced more accurately than arbitrarily connected sequences lacking causal relations. Bauer and Mandler (1989) also found that irrelevant actions within otherwise causally connected action sequences tended to be displaced or omitted, resembling the spontaneous reintroduction of order found by Bower et al. (1979). Evidence from developmental psychology, therefore, shows that from a very early age children understand and use causal relations to organise their recall of events, an ability that may act as a precursor to fully formed hierarchically organised scripts that emerge around three years of age.

The concept of hierarchical organisation has also been used in the study of animal behaviour. Dawkins (1976a) has argued that hierarchical structure constitutes 'good design,' and so would be expected to have been favoured by natural selection. Indeed, one example of hierarchically organised behaviour given by Dawkins (1976a, pp. 42-43), that of a predator catching prey, bears a striking resemblance to Schank and Abelson's (1977) restaurant script: the overall goal of 'catching prey' is broken down into lower level components ('searching,' 'pursuit,' 'killing' and 'eating'), each of which contain further lower level action rules. While this example was hypothetical, Dawkins (1976a) presents in more

[2]Strictly, many of the links described here are enabling rather than causal. For example, the act of opening a door *enables*, but does not in itself *cause*, the subsequent act of passing through the door. For simplicity of expression, however, further references to 'causal connections' imply either causal or enabling relations.

detail analyses of blowfly grooming and fish behaviour that demonstrate hierarchical organisation.

Recent work on social learning in primates has also focused on the hierarchical nature of what is learned. Byrne and Russon (1998) have argued that imitation can occur at two levels: the action level, which contains the basic constituent acts; and the program level, which constitutes the higher-level hierarchical organisation of those constituent acts. For example, the process by which mountain gorillas prepare the herb galium for consumption could potentially be imitated at any of several hierarchical levels, from the overall goal ('eat galium'), to more detailed sub-goals ('repeatedly pick green strands of galium with one hand...'), down to the fine motor details of the actions ('pick out a strand of green galium from the mass with any precision grip of the left hand...'). In Byrne and Russon's (1998) terminology, program level imitation involves copying the second of these, at the sub-goal level. Using observational data concerning gorillas and orang-utans, they go on to argue that imitation in great apes is primarily at the program level, with occasional action level imitation occurring for social functions (although see Stoinksi, Wrate, Ure & Whiten 2001 for experimental evidence that failed to find program level imitation in gorillas).

Whiten (2002), meanwhile, has investigated imitation of similar hierarchical structures experimentally. Three-year-old children observed an adult opening an artificial fruit in one of two hierarchically different ways, row-wise or column-wise. The children were statistically more likely to adopt the hierarchical organisation that they observed, while the sequential order within the subroutines of that hierarchy (within-rows or within-columns) was not copied. This thus represents an extension of Bauer and Mandler's (1989) work on imitation in younger infants, demonstrating that by three years of age children can imitate high-level hierarchical information. Although these studies of primates and preverbal children are investigating the behavioural *execution* of script events rather than the knowledge of such events represented in memory, script theory would predict the two should match, insofar as the script knowledge is built up from previous behavioural experiences of events.

To summarise, the evidence outlined above suggests that humans and some other species represent knowledge of routine events or stereotypical

action sequences hierarchically, and tend to show better memory for, and imitation of, actions that are represented at a relatively high-level of that hierarchy. The present study was designed to systematically test for such a 'hierarchical bias' in human cultural transmission, by passing descriptions of events entirely in terms of their low-level constituent actions along chains of participants. It was predicted that these low-level descriptions would gradually 'move up the hierarchy,' that is, the low-level actions would be subsumed into their higher level sub-goals, which would in turn be subsumed into the highest level overall goal. In essence, then, this study is coming full circle, updating Bartlett's (1932) original transmission chain studies, from which the concept of the 'schema' first emerged, with the past seventy years of schema research, the main contribution of which has been the concept of the hierarchy.

Methods

Design

The transmission chain design was adopted, in which the first participant in each chain recalls the original stimulus material, the output of which is then given to the second participant to recall, whose recall is in turn given to the third participant, and so on down the chain. Ten chains each containing four participants were run, with the first participant in each chain given the material reproduced in Table 1 constituting just the low-level actions of the hierarchy. The overall design is illustrated in Figure 2. Each chain transmitted all three scripts, with the order in which they were presented on the page counterbalanced.

The independent variable was the transmission generation, of which there were five: the original (F0) stimulus material and four recall generations (F1-F4). The dependent variable was the proportion of the total number of propositions recalled at each generation that was categorised at each hierarchical level (low, medium, high or none). It was predicted that, as the material is transmitted along the chain, the proportion of propositions classed as at the low-level in the hierarchy would significantly decrease, while the proportions classed as at the medium- and high-levels would significantly increase.

Table 1

Descriptions of the action scripts at each hierarchical level. Only the low-level descriptions were given to the first participant in each chain

Going to a restaurant
Low-level (given to the first generation): John and Nancy entered the restaurant and were shown to a table by the waitress. They sat down on the chairs and placed napkins on their laps. Then they looked at the menu and decided what food to have. They signalled to the waitress and told her their order, which the waitress wrote down. John and Nancy drank wine and talked until their food arrived. They ate the main course, then they had dessert. John asked for the bill, and the waitress brought it over. John took out his wallet and left money, as well as a tip. Then they both stood up and went to the cloakroom to fetch their coats. John and Nancy put on their coats and walked outside. (122 words, 10 sentences, 25 propositions)
Medium-level: John and Nancy sat down (1), ordered their food (2), ate their food (3), paid the bill (4) and left (5).
High-level: John and Nancy went to a restaurant.
Grocery shopping
Low-level (given to the first generation): Rachel parked her car outside the supermarket. She got out of her car, collected a trolley and wheeled it inside. She checked her list and went down the aisles. She put the items that were on her list into her trolley until she had them all. Then Rachel went to the checkout where she joined the fastest queue. She waited in the queue, and then unloaded her items onto the belt. The cashier rang up the items on the till and told Rachel the total. Rachel gave the cashier some money and the cashier gave Rachel her change. Rachel put the shopping into the bags and put the bags into the trolley. She wheeled the trolley out to her car and put the bags into the boot before driving away. (130 words, 10 sentences, 25 propositions)
Medium-level: Rachel arrived at the supermarket (1), got items (2), queued (3), paid (4) and left (5).
High-level: Rachel went shopping.

Materials

The material was derived from Bower et al.'s (1979) Experiment 1, in which 161 participants were asked to generate a sequence of actions that best describe a routine everyday event, specifically going to a restaurant, attending a lecture, getting up, grocery shopping and visiting a doctor.

Table 1

(Continued)

Getting up
Low-level (given to the first generation): Ian woke up and switched off the alarm. He lay in bed and stretched, then stood up. Ian went into the bathroom and turned on the shower. He washed himself then dried off with a towel. Then Ian went back into the bedroom and picked out some clothes from his wardrobe. He put on the clothes and checked himself in the mirror. Ian went downstairs and made some tea and some toast. He ate the toast while reading the newspaper. Then Ian got the books that he needed, put on his shoes and his coat and went outside. (98 words, 9 sentences, 25 propositions)
Medium-level:
Ian got out of bed (1), had a shower (2), got dressed (3), had breakfast (4) and left the house (5).
High-level: Ian got up.

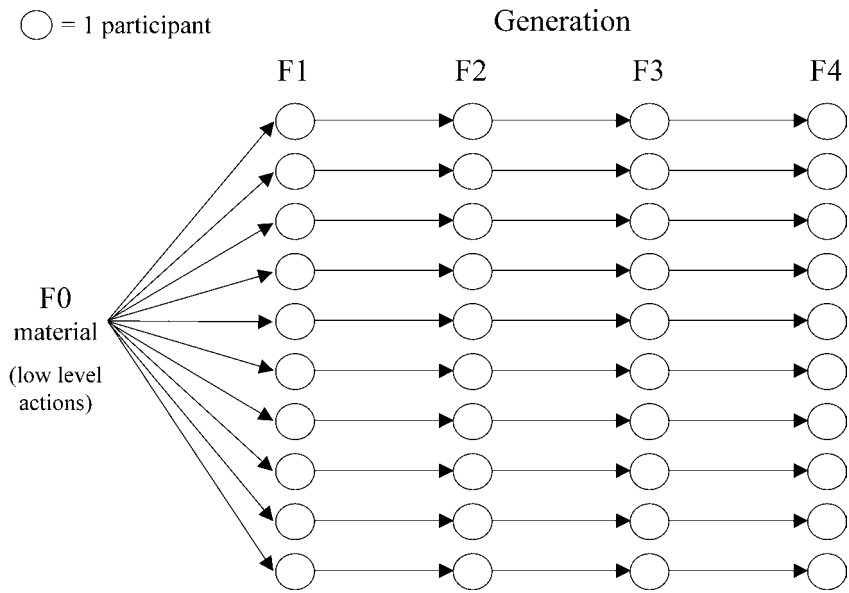

Figure 2. The transmission chain design.

Table 2 in Bower et al. (1979) lists every action mentioned by at least 25% of participants, and these actions were used to construct the hierarchical descriptions shown in our Table 1 concerning three of those action scripts: going to a restaurant, getting up, and going shopping.

The descriptions in Table 1 were designed to contain identical hierarchical structures in terms of their underlying propositions (see Coding section below for details of propositions). Each script contained a single high-level proposition which branched out into five medium-level propositions, each of which in turn branched out into five low-level propositions (giving 25 low-level propositions in total), similar to the structure shown in Figure 1. The low-level propositions roughly correspond to those actions generated by 25-50% of Bower et al.'s (1979) participants, the medium-level to actions generated by 50-75% of Bower et al.'s (1979) participants, and the high-level proposition to the overall heading originally presented by Bower et al. (1979) to their participants. No proposition was present at more than one level of the hierarchy. Note that the structure does not correspond exactly with every one of the actions in Bower et al.'s (1979) Table 2 as it was necessary that each of the three scripts contained the same number of propositions at each hierarchical level. Minor changes were also made to make the text more easily understood by modern day British participants.

Coding

A propositional analysis (Kintsch 1974) was performed on each participant's recall. Propositional analysis was developed to represent meaning in texts, and the number of propositions contained in a text has been shown by Kintsch (1974) to determine reading times and subsequent comprehension. As such it is a more meaningful measure of recall than the number of words or sentences. The text was divided into separate propositions, each proposition defined as a predicate plus a series of ordered arguments. A predicate is a verb, adjective or other relational term, while an argument is the complementary noun(s). For example, the sentence

> "Rachel gave the cashier some money and the cashier gave Rachel her change"

would be represented in terms of propositions as

GIVE, RACHEL, CASHIER, MONEY

GIVE, CASHIER, RACHEL, CHANGE

In the present analysis, the names of the characters and the tense were considered unimportant to the hypothesis, and so were ignored. The couple in the restaurant script was also considered as a single unit, rather than two separate people, in order to match the other two scripts. Once the propositional analysis had been performed, the recall was then compared to the structure presented in Table 1, with each proposition classed as either low-, medium- or high-level (or 'none' if not present at any level of the hierarchy).

To assess inter-rater reliability, an independent coder blind to the nature and hypotheses of the study performed the entire coding procedure for three of the ten chains. That is, the second coder divided each recall into propositions and classed each as low, medium, high or none, although the terms low, medium and high were replaced with the nondescript labels A, B and C. The coding of the blind second coder and the first coder (AM) were highly correlated, with a Pearson's correlation coefficient of 0.93.

A problem that arose during coding concerned the high-level Getting Up proposition. While this proposition ('Ian got up') was frequently produced by the participants, it was obvious from the context that the intended meaning was closer to the first medium-level proposition ('Ian got out of bed'), rather than the entire act of getting out of bed, showering, dressing, having breakfast and leaving the house. It was therefore decided to code each of these propositions as medium-level, in effect eliminating the Getting Up high-level proposition.

Participants

Nineteen male and twenty-one female participants, of mean age 20.59 years, were assigned randomly to one of the ten chains. All were students of the University of St Andrews and were unpaid. All participants spoke English as their first language (or had passed entry examinations demonstrating that their English was of a sufficient standard to study at a British university). All participants had normal reading and writing skills.

Procedure

The procedure adopted here involved the experimenter passing the material along the chains, rather than the participants themselves transmitting the material. This allowed greater control over transmission, and removed the need to gather groups of participants together. Participants were thus run in groups of between one and five.

Each participant was given a four-page booklet. The front page instructed the participant to read the passage printed on the second page once at a comfortable reading speed. The second page contained the material to be recalled, as appropriate to that chain and generation. At no point in the printed instructions or by the experimenter were the participants informed that they would have to recall this material later. The third page contained the instructions:

> "In the space below, please write out the text you just read as best you can. Try to be as accurate as possible, but don't worry if you can't remember it all. Spelling is not important. When you have finished, turn the page."

This was followed by a blank space for recall, for which no time limit was given. The final page solicited the participant's age and gender, and thanked them for taking part. The experimenter then debriefed them as to the nature of the study. Their recall was then typed up, correcting for spelling and grammar, and inserted into the next generation's booklet as appropriate.

Results

As predicted for this transmission chain design, the total number of propositions and words decreased with generation. One-way repeated-measures ANOVAs confirmed significant effects of generation on the total number of words ($F_{(1,13)} = 282.67$, $p < 0.01$) and propositions ($F_{(1,11)} = 217.37$, $p < 0.01$) contained in each recall (both of these tests violated the assumption of sphericity, therefore the Greenhouse-Geisser corrected significance level is reported). Figure 3 shows the more meaningful of these two measures of recall, the number of propositions, broken down into the three scripts. A 3 × 5 (story × generation) repeated measures ANOVA showed no significant differences between the three

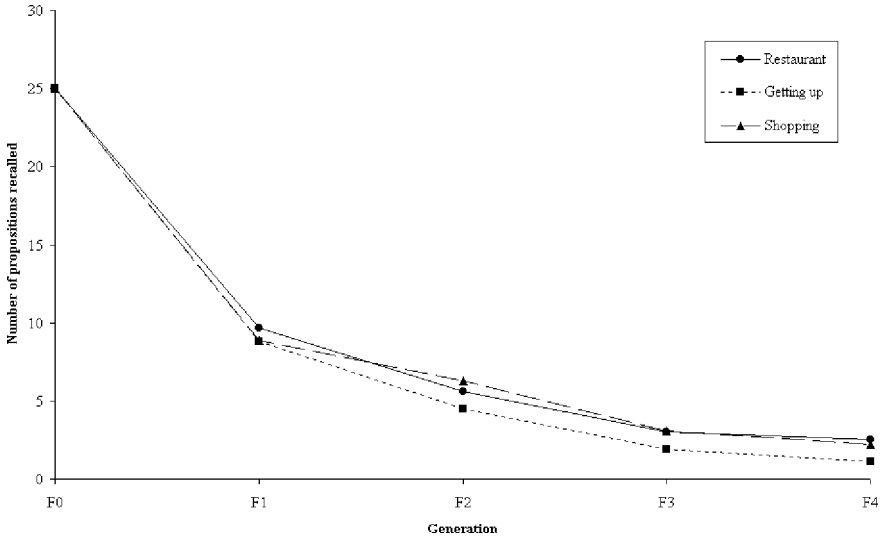

Figure 3. The total number of propositions recalled by each generation, broken down into the three scripts.

scripts ($F_{(2,18)} = 0.85$, ns). Data for the three scripts were therefore combined in subsequent analyses.

Figure 4 shows the proportion of the recall of each generation that was classified as either low-, medium- or high-level in the script hierarchy, or 'none' if the proposition was not present at any level. Inspection of Figure 4 appears to confirm the prediction that the proportion of low-level information would decrease with generation and the proportion of medium- and high-level information would increase. Information not present at any level ('none') initially increased to around 0.2 of the total propositions recalled, then neither increased nor decreased in a linear fashion. To test these trends statistically, linear trend analyses were performed on each hierarchical category separately.

Trend analyses

Trend analyses were performed first including the original F0 stimulus material (i.e. five generations F0-F4) and second excluding F0, including just the four recall generations (F1-F4). On the one hand, it was felt that excluding F0 would lose the contribution of the first (F1) participant in each chain in initially transforming the F0 material. On the other hand,

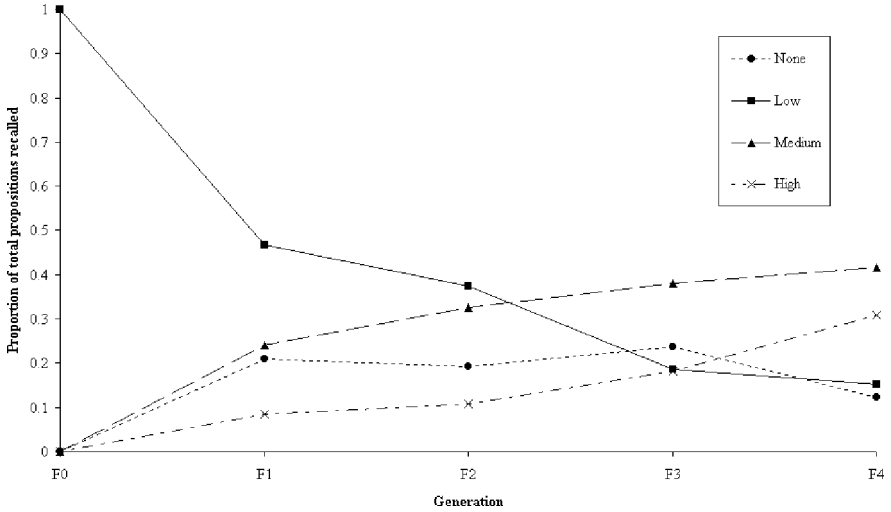

Figure 4. The proportion of the total propositions recalled by each generation that was classed at each hierarchical level. Data from the three scripts are combined. 'None' refers to propositions not contained anywhere in the script hierarchy.

it was also of interest whether the four recall generations (F1-F4) would alone show the predicted trends, as F0 was in a sense engineered by the experimenter with the hypothesis in mind.

The following analyses were performed on all five generations, including the original F0 stimulus material. Four separate one-way repeated measures ANOVAs were performed, one for each hierarchical category (low, medium, high and none). Where the assumption of sphericity is violated, Greenhouse-Geisser corrected significance levels are reported. The ANOVAs revealed significant effects of generation at each of the four levels (Low: $F_{(4,36)} = 78.05$, $p < 0.01$; Medium: $F_{(1,11)} = 7.96$, $p < 0.05$, Greenhouse-Geisser corrected; High: $F_{(1,11)} = 7.40$, $p < 0.05$, Greenhouse-Geisser corrected; None: $F_{(2,21)} = 4.18$, $p < 0.05$, Greenhouse-Geisser corrected). The trend analyses revealed that the low-level proportion showed a significant linear decrease with generation ($F_{(1,9)} = 175.92$, $p < 0.01$), while the medium-level proportion ($F_{(1,9)} = 10.41$, $p < 0.01$) and the high-level proportion ($F_{(1,9)} = 11.82$, $p < 0.01$) showed separate significant linear increases with generation. The 'none' proportion showed no significant linear trend ($F_{(1,9)} = 3.30$,

ns). These trend analyses therefore confirm the prediction that low-level information would significantly decrease with generation, and medium- and high-level information would significantly increase.

The following analyses were performed after excluding the original F0 stimulus material, leaving the four recall generations (F1-F4). The low-level proportion again showed a significant effect of generation ($F_{(3,27)} = 13.68$, $p < 0.01$), and a trend analysis again revealed a significant linear decrease with generation ($F_{(1,9)} = 22.30$, $p < 0.01$). The medium-level proportion, however, showed no significant effect of generation ($F_{(1,11)} = 1.55$, ns, Greenhouse-Geisser corrected) and thus no significant trend. The high-level proportion showed no significant effect of generation using the Greenhouse-Geisser correction ($F_{(1,11)} = 4.60$, ns), although this became significant with the less conservative Huynh-Feldt correction ($F_{(1,11)} = 4.60$, $p < 0.05$). If the latter correction is accepted, then there was a significant linear increase with generation ($F_{(1,9)} = 5.55$, $p < 0.05$). Finally, there was no effect of generation for the 'none' proportion ($F_{(3,27)} = 0.87$, ns).

One reason for the lack of a significant trend for the medium-level after the first generation may have been that while low-level propositions were being converted into medium-level propositions, medium-level propositions were in turn being converted into high-level propositions, with the net change at the medium-level being zero. An analysis was therefore performed on the combined proportion of medium- and high-level propositions, resulting in a significant effect of generation ($F_{(2,16)} = 7.84$, $p < 0.01$, Greenhouse-Geisser corrected) and a significant linear increase with generation ($F_{(1,9)} = 13.75$, $p < 0.01$).

In summary, the trend analyses support the hypothesis that information moves up the hierarchy as it is passed along the transmission chain. Including the original F0 stimulus material in the analyses, there was a significant decrease in low-level information and separate significant increases in both medium- and high-level information. As might be expected given that the F0 material was specifically designed with the hypothesis in mind, excluding the F0 material gave a somewhat less robust effect, although the hypothesis was still supported. There was again a significant decrease in low-level information, and a significant increase in medium- and high-level information combined, although not separately. The fact that there was a

significant effect despite removing the contribution of the first generation confirms the value of the transmission chain method over and above a standard single generation memory experiment. Finally, information not contained within the hierarchy showed no linear increase or decrease with generation, both with and without F0.

Deviations of order

Abelson (1981) has argued that 'strong' scripts, such as the ones used in this study, contain implicit information on the correct order of sub-goals, often dictated by causal or enabling relations between those sub-goals. For example, eating food in a restaurant can only be achieved once ordering is completed: ordering *enables* eating. The finding by Bower et al. (1979) that scrambled scripts were corrected into their canonical order supports this assertion.

In line with this, the order of both medium- and low-level propositions was transmitted almost entirely intact in the present study. Only one of the 163 medium-level propositions recalled by all forty participants deviated from the original medium-level order in the stimulus F0 material. This single violation occurred in a first generation recall of the Getting Up script, where the character was described as having a shower *after* getting dressed. Although this is possible, it is highly improbable, and a closer inspection revealed that the recall in fact reads more like a list of actions with no temporal or causal connections: "He gets dressed *and* he has a shower" (italics added), rather than a temporally connected narrative (which might use 'then' rather than 'and'). It may be no coincidence, then, that the next generation in this chain lost the Getting Up script entirely, given that script-like narratives should be more likely to be remembered than unconnected lists of events.

Similarly, only three of the 241 low-level propositions that were recalled deviated from the original low-level order. The first consisted of the couple in the restaurant drinking wine after eating their meal, rather than before. Such a deviation might be expected, as wine can be, and usually is, drunk before, during and after a meal. The other two deviations were identical but from different chains (an instance of 'convergent cultural evolution'?), and consisted of the Getting Up character going downstairs before having a shower, rather than after. However, it should be noted that

the student residences in which all of the participants lived have showers on the ground floor, perhaps explaining this change in order. If this is indeed the reason, then this is an interesting example of how recent experience shapes underlying scripts, and hence also shapes immediate recall of script-like descriptions.

Illustrative examples

A representative chain illustrating the 'hierarchisation' of the original low-level material is reproduced in Appendix 1. Although the script shows a drastic reduction in length, there is an intuitive sense that the 'gist' or 'core' of the story has been preserved right through the chain. In terms of the theory presented here, this is the result of the script being described at progressively higher hierarchical levels. This can also be observed, with low-level actions (e.g. giving money to the cashier and receiving change in return) gradually being subsumed into higher order sub-goals (e.g. 'paying').

Two more specific examples illustrate the hierarchical bias further. First, in one of the chains the three separate scripts merged to form a single narrative. For example, one fourth generation recall stated:

> "Ian woke up and ate breakfast. Nancy went to the supermarket for shopping. Afterwards they both met up and had lunch."

Here, the two originally different characters from the Getting Up and Shopping scripts became the two characters in the Restaurant script, creating a single narrative of their day. Details of the restaurant are also lost, becoming 'having lunch.' The second example comes from another fourth generation recall, in which a participant forgets one of the stories (Getting Up) and invents a completely new one. While the content is forgotten, however, the hierarchical level of description, roughly corresponding to the medium-level of the other scripts, is perfectly preserved:

> "Peter went to the cinema and watched a movie and went home."

These two phenomena – imposing links to turn three fragments into a single narrative, and preserving the script-like structure despite entirely forgetting the content – illustrate a seeming compulsion to describe actions and events in terms of highly structured script-like representations, and provide additional evidence for the psychological reality of script theory.

Discussion

The aim of the present study was to investigate the possible operation of a 'hierarchical bias' in the cultural transmission of event knowledge. This bias is hypothesised to impose a script-like hierarchical structure onto descriptions of such events, and progressively subsume low-level actions into their higher level goals as the descriptions are passed from person to person. This was tested by passing short descriptions of three scripts (going to a restaurant, getting up and going shopping) consisting entirely of information at a relatively low hierarchical level along multiple chains of participants. The results confirmed that as these low-level descriptions were passed along the chains, there was a significant linear decrease in low-level information, and a significant linear increase in medium- and high-level information.

These significant linear trends, demonstrating a cumulative increase or decrease in information with generation at specific hierarchical levels, illustrate the value of the transmission chain method over standard single generation memory experiments, and confirm that the effect is genuinely 'cultural.' It can be hypothesised that this experimental finding of a hierarchical bias using the transmission chain method can be extrapolated to human cultural transmission more generally, and a similar process would be observed whenever information concerning everyday events is passed from person to person in the population as a whole.

As well as elucidating a particular aspect of cultural transmission, this result also provides support for the psychological reality of script theory (Schank & Abelson 1977), complementing studies such as Bower et al. (1979) and Zacks et al. (2001). In addition to the main finding, it was also found that the canonical order of the medium- and low-level actions was preserved in the vast majority of recalls, as predicted by Abelson (1981). It was further found that causal connections were imposed on script fragments to form a single narrative, and that even where the content of a script was entirely forgotten the high-level hierarchical structure was retained, both of which suggest that events are represented in a highly structured fashion.

The demonstration of a hierarchical bias in human cultural transmission also adds plausibility to the prediction made by Byrne and Russon (1998) that non-human primates are most likely to successfully imitate

actions at a relatively high ('program') level of the hierarchy. Although the present study examined verbally-expressed knowledge of events rather than the behavioural execution of such acts, script theory predicts that the two would be matched, given that script knowledge is shaped by past behavioural experience of such events. Furthermore, Whiten (2002) has demonstrated hierarchical imitation in human children, suggesting that the hierarchical bias can be extrapolated to the perception of actions, and this begs testing in other primate species. Although initially it would be desirable to experimentally demonstrate the one-to-one imitation of hierarchical structure as suggested by Whiten (2002), ultimately it may be fruitful to adapt the method used in the present study, to see whether hierarchical structure can be transmitted along chains of non-human primates. Indeed, based on the results reported here, marked effects may not be observed for several generations.

The identification of hierarchical structure in human cultural transmission is also relevant to memetics, which argues that human culture evolves through the differential transmission of discrete 'cultural replicators,' or 'memes,' loosely analogous to genes (Dawkins 1976b; see Aunger 2000 and Mesoudi, Whiten & Laland 2004 for further discussion of cultural evolution and memes). One major criticism of the memetics literature is that memes are too ephemeral to function as replicators, because the mutation rate is too high to provide sufficient copying fidelity (e.g. Dennett 1995). However, Plotkin (1996; 2000) has suggested that if culturally transmitted information is hierarchically structured, then although information at the low or surface level of the hierarchy may not have sufficient copying fidelity, information higher up the hierarchy at a deeper level may change slowly enough to constitute genuine cultural replicators. The results of the present study suggest that this may be the case, with the core high-level information (e.g. going to a restaurant) showing much greater copying fidelity than the low-level details. Memeticists looking to identify memes might therefore be advised to start with such high-level structures.

Extensive evidence was presented in the Introduction for the tendency of adults, children and non-human species to represent events hierarchically, and show superior recall and imitation of information at relatively high-levels of that hierarchy. The present study confirmed the operation of a hierarchical bias in human cultural transmission. What, however, is

the functional significance of this hierarchical bias to cultural transmission? The answer may lie in Bartlett's (1932) explanation for his finding that folk tales, even unfamiliar folk tales, were transmitted with far greater fidelity than any other material, such as newspaper reports and scientific arguments. Bartlett (1932) argued that this occurred because people already possessed story schemas, around which they could reconstruct the particular story they had read. In the present case of action scripts, an even stronger argument can be made. As well as possessing the hierarchical structure of everyday events, the participants studied here would also possess the *content* of scripts such as going to a restaurant or getting up. Given that everyone in a society shares the same implicit script knowledge, then it is more efficient to transmit only the high-level goals or medium-level sub-goals, as it can be assumed that people can reconstruct for themselves the constituent low-level actions. In other words, the low-level information is redundant, and so can be removed without any loss in the intended message.

The evidence presented in the Introduction suggests that the key assumption upon which this explanation rests – that everyone in a society shares the implicit structure and content of action scripts – is a good one. Bower et al. (1979) and Nelson and Gruendel (1986) found substantial agreement amongst adults and children respectively on the actions that make up common scripts and their hierarchical structure, while Bauer and Mandler (1989) found evidence for very early development of an understanding of causally linked script-like sequences of actions.

Two predictions follow from this explanation. First, if the low-level information is indeed redundant, then it should be possible for new participants to reconstruct an approximation of the original F0 material from just the final F4 recalls produced in this study (given appropriate instructions such as 'make up a typical story based around the following sentence'). Second, if the low-level information is made non-redundant, i.e. it cannot be reconstructed just from the high-level sub-goals, then it should be preserved as well as the higher levels. This would occur if the low-level information is not part of the usual script. Just such an effect was observed by Bower et al. (1979), who found that unexpected intrusions to the script were more likely to be recalled than routine script actions. However, this only occurred for intrusions that constituted interruptions in the causal

structure of the script, such as an obstacle to a sub-goal (e.g. the menu is in French) or a distraction that sets up a new goal (e.g. the waitress spills soup on the customer, requiring a trip to the bathroom). Intrusions that constituted simple errors that did not affect the causal structure were recalled less well than routine script actions. This resembles the finding by Bauer and Mandler (1989) that infants omitted causally-irrelevant actions when imitating sequences of actions. Causally-relevant intrusions should, therefore, be preserved during transmission.

Alternatively, the participant could be instructed to write out the story for an imaginary recipient who they know does *not* possess the implicit script, such as a hunter gatherer unfamiliar with restaurants or supermarkets. This latter test assumes, however, that the hierarchical bias is under conscious or intentional control, rather than an unconscious constraint on memory, in itself an interesting question that further experiments could investigate.

As well as altering the material, it may also be of interest to repeat the present study with different populations. Although non-Western populations might not possess the scripts that have been studied by Western psychologists, such as visiting a restaurant or going shopping, we anticipate that they would possess just as highly structured scripts for stereotyped routine events in their own societies, for which the hierarchical bias should operate. There is also evidence that autistic individuals show a difficulty in generating scripts (Trillingsgaard 1999), suggesting that they would not show a hierarchical bias. Indeed, this deficit might be predicted from the theory outlined above. Autistic individuals, who have difficulty representing other people's mental states, might not be able to make the assumption that other people possess implicit knowledge of script events, in which case the low-level information would not be redundant.

One final point concerns the relation between the hierarchical bias found here and what is colloquially known as 'summarising.' Many of the fourth generation recalls obtained in the present study resemble summaries of the original F0 stimulus material (see, for example, Appendix 1), suggesting that the act of summarising a text entails the same process as hierarchisation during transmission, i.e. the retention of the high-level information and the discarding of low-level details (see also Kintsch & van Dijk 1978, who describe similar constructive and reproductive processes

in both recall and summarization of texts in general). Indeed, it might be that if a single person is asked to summarise the material used here, the result would look similar to the cumulative product of asking four people to copy the material exactly. A specific instance of this might even be found at the beginning of this report: the abstract of a scientific paper represents the high-level hierarchical content of the entire report, containing the main rationale, findings and implications, and discarding the intricate methodological details (Kintsch & van Dijk 1978). Intriguingly, the results of the present study suggest that a summary in terms of high-level hierarchical information, such as a scientific abstract, should be highly conducive to cultural transmission. Given that a successful scientist is partly one whose ideas are disseminated the most widely, perhaps the role of abstract writing in science is being greatly underestimated.

Appendix 1

Rachel parked her car outside the supermarket. She got out of her car, collected a trolley and wheeled it inside. She checked her list and went down the aisles. She put the items that were on her list into her trolley until she had them all. Then Rachel went to the checkout where she joined the fastest queue. She waited in the queue, and then unloaded her items onto the belt. The cashier rang up the items on the till and told Rachel the total. Rachel gave the cashier some money and the cashier gave Rachel her change. Rachel put the shopping into the bags and put the bags into the trolley. She wheeled the trolley out to her car and put the bags into the boot before driving away. (F0)

Rachel went shopping, parked her car at the supermarket, got out of the car, got a trolley, went into the supermarket and collected the food she wanted. She went to pay for the goods, gave the cashier the money, he gave her change and a receipt. Then she took the trolley back and then drove off in her car. (F1)

Rachel drove to a supermarket, parked her car, got a trolley and chose some food. Then she went to the cashier to pay for her food. The cashier gave her some change. Then she put back the trolley and drove away. (F2)

Rachel drove to the supermarket, parked her car, got a trolley and chose some food. She paid the cashier and drove home. (F3)

Rachel went to the supermarket, got some food and went home. (F4)

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