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Transformation between scientific and social representations of conception: The method of serial reproduction

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The social representation (SR) of conception was investigated using an adapted version of Bartlett's (1932) method of serial reproduction. A sample of 75 participants reproduced a text describing the conception process in 20 segregated chains of four reproductive generations. Changes in sentence structure and content were analysed. Results indicated that when the scientific representation of conception is apprehended by laypersons, two different processes take place. First, the abstract biological description of the process is progressively transformed into an anthropomorphic description centred on the sperm and ovum (personification). Second, stereotypical sex-role attributes are projected onto the sperm and ovum. Limitations of the method of serial reproduction are discussed, as well as its potential for modelling processes of cultural diffusion of knowledge.

Social representations and common sense

Social representations (SRs) can be defined as collective beliefs held by social groups concerning specific objects relevant to them. Social representations are social in at least two ways. First, they are socially shared (Jaspars & Fraser, 1984). Second, they are social because they are collectively elaborated in everyday interpersonal interaction. They function in order to make sense of reality: by constructing representations of specific aspects of reality, groups and cultures stabilize and insulate their products (ideologies, practices, beliefs) from outside influence. For example, representing AIDS as a divine punishment legitimates discrimination against gay men (Moscovici, 1998).

The SR approach is highly relevant for a social psychological study of common sense. A fundamental notion in this approach is that common sense is, in a highly interconnected society of experts, a dynamically evolving and heterogeneous product derived from many different sources, prominent among them older, traditional belief systems and transformed scientific knowledge (Flick, 1998). Social representations constitute a subcategory of common sense. More specifically, SRs are those hybrid products that arise when laypersons apprehend the discourse of experts diffused through the mass media. They are hybrid because expert discourse, in particular scientific discourse, is both cognitively inaccessible and potentially ideologically

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threatening and is inevitably transformed through its diffusion in mass media, as well as in conversation and social interaction. In SR research, and in other approaches to the study of everyday social life, it is accepted that talk is an ubiquitous sense-making practice, and the basis of the social construction of reality (Berger & Luckmann, 1966; Edwards & Middleton, 1987; Moscovici, 1994). In this way, transformations of meaning arise when groups come into contact with new and unfamiliar ways of thinking. Because of the threat posed by these ideas for collective identity, members of a group or culture are motivated to communicate with each other about these ideas or concepts, and to anchor them in a shared social reality. Thus, psychoanalysis is assimilated to the religious rite of confession (Moscovici, 1961), social representations of madness are anchored in ideas about organic illness (Jodelet, 1991), and laypersons conceptualize the biological process of fertilization by applying metaphors taken from everyday experience (Wagner, Elejabarrieta, & Lahnsteiner, 1995). Through such processes, the potentially menacing effects of innovative ways of thinking (e.g. new scientific insights into traditional areas of knowledge) on collective belief systems are defused and the status quo is maintained. These processes constitute an important aspect of post-modern culture, where bodies of discourse produced by expert sources (such as science) have displaced many of the formerly authoritative sources of knowledge (such as religion), and play an important role in the validation of beliefs, assumptions, procedures and the regulation of social practices (Thommen, Cranach, & Ammann, 1992; Wagner, 1994).

Social representations and conventionalization: The work of Bartlett

From the above discussion, it seems that SR research has also developed a unique theoretical perspective on a social psychology of culture. It has done so by focusing on cultural transformation (i.e. on how cultural products are modified when they are diffused beyond the boundaries of a culture or subculture). Since scientific knowledge is an important cultural form in modern societies, special emphasis is placed on understanding how scientific knowledge is reconstructed by and integrated into, and how it regenerates, common sense (Farr, 1993). Thus, the SR approach provides a powerful theoretical framework oriented towards the study of cultural *processes*. This theoretical emphasis is reflected, for example, in Moscovici's (1961) work on the transformation of psychoanalysis in various media, including his distinction between processes of anchoring and objectification, and between different systems of communication, such as diffusion, propagation and propaganda. However, more recent empirical work on SR has often neglected the study of processes in favour of structurally oriented research, for example the research on the central-peripheral structure of SR (Moliner, 1995).

Nevertheless, on the theoretical level, this focus on process makes the SR approach remarkably similar to Bartlett's (1932) social psychology of culture, especially his discussion of the phenomenon of conventionalization. Conventionalization, defined by Bartlett (1932, p. 245) as 'the principles by which items, or systems, of culture, moving about from one group to another, undergo change, and finally arrive at relatively fixed and stable forms in whatever group they reach', is very similar to the above-mentioned phenomena studied by SR research. Although Bartlett's work has

been widely acknowledged in SR theory (e.g. Farr, 1990; Jodelet, 1992; Moscovici, 1984, 1990), there is little to be found on the precise nature of his contribution. In particular, until recently there has been no systematic treatment of the relation between Bartlett's (1932) theory of conventionalization and SR. An exception is Saito (1996), who discusses theoretical relationships between conventionalization and SR, presenting an illustrative case study of the different conceptions of Zen Buddhism in Britain and Japan. Even so, systematic empirical research is lacking. The purpose of the present study is to explore these relationships on a methodological and empirical level.

The methodological counterpart of conventionalization is the method of *serial reproduction*. Its basic principle is as follows (Bartlett, 1932): some text or picture material is given to a participant who must, after a suitable interval to study it, reproduce it from memory as accurately as possible. This reproduction is then given to a second participant who must also reproduce it, and so on with the third and subsequent participants. In this way, a series of texts (or drawings) is produced, which contains transformations of content which can be described in different ways. Bartlett applied this method to various types of material, including pictures and descriptive and argumentative texts.

The potential of the method has been criticized, both as a technique to study memory (Gauld & Stephenson, 1967) and as a tool for simulating collective memory in interpersonal communication. For example, serial reproduction does not take into account the interactive nature of communication and its impact on the outcome of discussion (Middleton & Edwards, 1990). However, there are reasons to suppose that serial reproduction might be suited to simulating some aspects of cultural transformation involved in the genesis of SR (Kashima, 2000). This is discussed in what follows.

Serial reproduction as a method for studying cultural transformation

The method of serial reproduction has seen sporadic use in other areas of psychology. Allport and Postman (1945) applied a variant of it in their classical research on wartime rumour. In a set of experimental studies, participants successively described picture material depicting battle scenes or urban themes. In one case, the original picture depicted a black man and a white man apparently talking to each other in a subway. The white man had a razor in his hand. The authors report the following transformations (p. 111): 'In over half the experiments with this picture, at some stage in the series of reports the Negro (instead of the white man) is said to hold the razor in his hand. Several times he was reported as brandishing it wildly or as threatening the white man with it.' Such results were interpreted by the authors as a case of 'motivated assimilation' to the racial prejudice against African Americans widely prevalent at the time. Allport and Postman emphasize the similarities between social memory and rumour: because many individuals are involved in both cases, the meaning that emerges as a result of these processes is common to the social group or culture to which the individuals belong.

In another study, also in a context of social conflict (Haque & Sabir, 1975), serial reproduction was used to study Pakistani stereotypes of the Indian army in the

aftermath of the Indo-Pakistan war of 1965. The authors used serial reproduction on a text describing the Indian army. After eight reproductions, the original text of 331 words had been reduced to two sentences, one of which stated that 'it has been proved that the Indian Army is inefficient for a war' (p. 59). The authors concluded (p. 60) that 'the complicated and unstructured passage through selective filtering and assimilation to cultural stereotypes became more meaningful, believable, and communicable'.

These studies have two things in common. First, they operate exclusively on the basis of single chains of reproduction. There is no indication that they systematically combined evidence from different and parallel chains of reproduction. This is an important point, since, as Allport and Postman (1945, p. 59) remark, significant distortions which are introduced by an individual tend to 'snowball' in the course of serial reproduction. Thus, variations in content in a single chain of reproduction are sensitive to idiosyncratic tendencies. Second, the analyses were restricted to qualitative and descriptive aspects, which limit the results obtained to an anecdotal level. In order to obtain better generalizability, it is necessary to adapt the technique to allow quantitative analysis. An adapted design featuring such innovations is shown in Fig. 1.

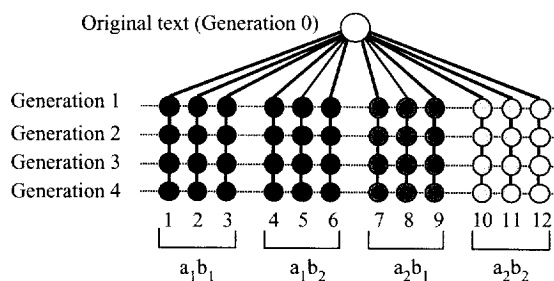


Figure 1. An adapted serial reproduction design. It incorporates a vertical dimension (4 reproductive generations) and a horizontal dimension (12 parallel chains of reproduction). A sample $A \times B$ factorial design is illustrated, where a_1 and a_2 are the levels of factor A and b_1 and b_2 are the levels of factor B.

The design encompasses a number of parallel chains of reproduction. Each text that is reproduced can be situated horizontally in a given 'chain' and vertically in a given 'generation'. According to the theoretical interests of the researcher, a number of independent variables can be incorporated into the design. These are operationalized as segregated chains of reproduction. The dependent variable would be any theoretically relevant feature of the texts: transformation of sentence structure, thematic novelty or decay, and so on. For example, one may study the effect of (A) gender (a_1 : male, a_2 : female) and (B) sex-role orientation (b_1 : conservative, b_2 : liberal) on the reproduction of a text describing a fictive interaction between a man and a woman. Participants from different cells of such a 2×2 design are assigned to different sets of chains of reproduction ($a_1b_1, a_1b_2, a_2b_1, a_2b_2$) in order to 'isolate' the effects of each cell (see Fig. 1). In such a design, the effect of serial reproduction (change over generations) can also be analysed as a within-participants

factor, since information is transmitted from one reproductive generation to the next. The empirical research reported here consists of an application of this procedure along the lines explained above, and is explained in the following section.

The present study: Scientific and social representations of conception

The present study is a replication and extension of Bangerter and Lehmann (1997), a pilot study applying the method of serial reproduction to the study of the SR of conception. The present study goes beyond it by enlarging the data base and incorporating new elements (e.g. between-participant independent variables as discussed above) into the design. The SR of conception involves the ways in which the biological process of conception is apprehended and represented by laypersons. As detailed above, such a representation implies a transformation of content in relation to a scientific representation of conception.

Wagner *et al.* (1995) investigated the role played by metaphor in objectification for the SR of conception. They assumed that the abstract and unfamiliar biological process of conception is apprehended by laypersons through assimilation to an area of experience with which they are familiar, and which is structurally similar to the conception process, namely their own everyday experience of sex roles and sexual behaviour. In an experimental questionnaire study, the authors demonstrated that participants preferred using sexual over non-sexual metaphors to describe the behaviour of sperm and ovum, and that ratings of different aspects of their behaviour corresponded to the projection of sex-role stereotypes onto the sperm and ovum. In addition, the results varied according to the sex-role orientation of the participants; liberally oriented participants exhibited less stereotyping than conservative participants.

However, the authors' focus on the interaction between sperm and ovum as central elements of the reproductive process obscures one of the most interesting aspects of the transformation of this particular scientific representation into common sense. In scientific discourse, conception is an exceedingly complex affair engaging knowledge from various disciplines (physiology, endocrinology, biochemistry and so on), and the interaction of sperm and ovum is only a part of this whole (Austin & Short, 1976). From a social psychological perspective, the more fundamental phenomenon is the process by which this complex affair is transformed into a situation in which two main actors, namely sperm and ovum, interact in a purposive and approximately anthropomorphic manner. Such a process is called *personification* (Lakoff & Johnson, 1980; Moscovici & Hewstone, 1983), in other words the projection of attributes of persons onto inanimate objects, plants or animals. Personification has been found to be an important component of children's naïve theories of biology (Hatano & Inagaki, 1994). However, by focusing *a priori* on the interaction between sperm and ovum, Wagner *et al.* (1995) excluded the possibility of investigating this. Therefore, Bangerter and Lehmann (1997) investigated the projection of sex-role stereotypes on sperm and ovum studied by Wagner *et al.* as a part of the more fundamental process of personification. They assumed that in the course of the transformation from the scientific representation of conception to a lay representation, a dual process would take place. First, textual features characteristic

of scientific discourse would disappear, whereas the role of sperm and ovum would be accentuated, and these would be depicted in an increasingly anthropomorphic manner. Second, and on the basis of the first process, sex-role stereotypical behaviour would be projected onto the sperm and ovum (i.e. their interaction and attributes would be described according to prevailing stereotypes of male-female interaction). Results partly confirmed these expectations.

The present study was designed to produce consistent evidence of personification and sex-role stereotyping in the transformation of a scientific text on conception through serial reproduction. As a linguistic phenomenon (Lakoff & Johnson, 1980), personification should be manifested in transformations of text content on the level of the sentence and its components. Sex-role stereotyping should be manifested primarily in sentences describing interaction between sperm and ovum, since such sentences are structurally analogous to descriptions of interactions between men and women (Wagner *et al.*, 1995). More specifically, in an investigation of sex-role stereotyping in print media, Kruse, Weimer, and Wagner (1988) analysed sentences depicting interaction between men and women, focusing on sentence verbs and subject and object roles. They found patterns indicating that gender interactions were still depicted according to traditional scripts. A similar procedure is applied in the present study.

The present study uses serial reproduction according to the design shown in Fig. 1. A short scientific text describing the conception process was reproduced by participants divided into separate chains of reproduction according to gender and sex-role orientation. It was expected that evidence for personification and stereotyping would be found, as well as a differential influence of sex-role orientation on stereotyping effects. Sex-role orientation was introduced as a variable following the results obtained by Wagner *et al.* (1995). It was expected that conservative participants would exhibit more stereotyping than liberal participants. Gender was introduced as a control variable, since gender self-stereotyping effects are known (Lorenzi-Cioldi, 1992). However, no specific effects of gender were hypothesized. Neither of these factors were assumed to affect personification.

Method

Participants

The sample comprised 75 German-speaking Swiss undergraduates (52 women and 23 men) from the University of Berne who participated in the study as part of a course requirement. The study was conducted in German, and was announced as a series of short, unrelated experiments.

Procedure

Approximately two weeks before the experiment, participants received by mail a sex-role inventory (Krampen, 1979) which they completed and mailed back. Participants were attributed to different chains of reproduction according to gender and sex-role orientation (liberal or conservative, median split). The study design comprised four reproductive generations (see Fig. 1). Thus, for the female-liberal cell, there were 28 participants distributed over seven reproductive chains of four generations each. For the female-conservative cell, there were 24 participants (four had to be excluded from the study because

their command of German was not sufficient or because they were attributed to the wrong place in the chain), also distributed over seven reproductive chains. However, because of the exclusions, two chains had only three reproductive generations and one had only two. For the male-liberal cell, there were 12 participants distributed into three chains of four generations each. For the male-conservative cell, one participant was excluded because he was attributed to the wrong place in the chain, yielding three chains of four generations and one chain with three generations.

Participants were tested in groups of 8 to 10 over a period of two weeks. The participants constituting the first generation arrived in a room for the experiment, where they received a sheet of paper on which the original text was printed. They were instructed to read it and to try to understand its content. They had approximately 12 min for this. After a short non-verbal distracting task (6 min), they were instructed to write down as exactly as possible what they had read before (20 min). The handwritten reproductions thus obtained were retyped and presented as originals to the second generation of participants, who completed the study under identical conditions either a few hours or a few days later. This procedure was repeated with the third and fourth generations. After all generations had completed the task, participants were debriefed.

The text used as the original for the serial reproduction was derived from Bangerter and Lehmann (1997), which was based on a textbook article on reproductive animal biology (Austin & Short, 1976). An expert (a university professor for reproductive animal biology) was consulted in order to ensure that the text was scientifically accurate. English translations of the German versions of the original text (290 words) and two sample fourth-generation reproductions are presented in the Appendix.

Hypotheses

The two main hypotheses of the study, concerning processes of personification and sex-role stereotyping, were operationalized as follows.

Personification. This process corresponds to an increasing focus of the text on the sperm and ovum, and a comparative decrease of descriptions of other processes and events. Also, sperm and ovum are increasingly depicted in an anthropomorphic manner. This was tested by analysing changes in sentence structure (Bangerter & Lehmann, 1997) on three levels. First, it was expected that the proportion of sentences with *action verbs* (verbs presupposing an active agent) would increase over reproductive generations, at the expense of state verbs or verbs describing processes happening to the subject. In research on implicit verb causality, action verbs imply attributions of causation, control or responsibility to the sentence subject (Rudolph & Försterling, 1997). This was assumed to be a precondition for personification. Second, it was expected that, over reproductive generations, the proportion of sentences with *things or objects* in the subject position would increase at the expense of the proportion of sentences with *events or processes* in the subject position. This was assumed to correspond to a schema of object causation, and is also a necessary aspect of personification: things, rather than processes, are depicted as causes of events. Third, it was expected that, among those sentences with things in the subject position, the proportion where the thing is one of the sexual cells (sperm or ovum) would increase in relation to the proportion of sentences where the thing is another object. This would reflect the focus of the text on the sexual cells as main actors.

Stereotyping. This hypothesis concerns the interaction between the sperm and ovum, as well as general descriptions of their behaviour. In the present study, analysis focused on two stereotypical dimensions which differentiate men from women: dominance vs. submissiveness and activity vs. passivity (Kruse *et al.*, 1988; Wagner *et al.*, 1995). It was expected that (dominance vs. submissiveness), of those sentences describing an interaction between sperm and ovum, the proportion of sentences with the sperm in the subject and the ovum in the object position would increase at the expense of the proportion of sentences with the ovum in the subject and sperm in the object position. A second dimension of sex-role related attributes (active vs. passive) concerns movement of the sperm and ovum to their meeting point. In the original text, both sperm and ovum are largely dependent on macrophysiological factors for transport. Independent navigation (e.g. 'swimming') on the part of the sexual cells plays a negligible role in this process. However, it is consistent with the sex-role stereotype of sperm as active and ovum as passive

for the sperm to be increasingly depicted as *actively travelling* to the meeting point (i.e. 'several thousand sperm arrive at the meeting place'), and for the ovum to be increasingly depicted as being *passively transported* (i.e. 'the ovum is transported by contractions').

Coding

The texts were prepared for analysis by segmenting all sentences into propositions containing only one verb. For each proposition, the variables relevant to the personification and stereotyping hypotheses were coded.

Verb type was coded (i.e. action verbs vs. other types). Action verbs express activity on the part of the subject (i.e. the sperm cells *arrive* in the vagina). In addition, for sentences with action verbs, the sentence subject was coded as either *things* (i.e. physical objects, e.g. sperm, ciliae, oestrogen) or *events* (e.g. contractions, current, fertilization). Things in the subject position of the sentence were further coded as either *sexual cells* (i.e. sperm or ovum), or *other* (e.g. ciliae).

For the stereotyping hypothesis, two types of sentences where sperm and ovum appear relative to one another in the subject and object position were analysed: (1) sperm in subject and ovum in object position (i.e. 'the sperm penetrate into the ovum'), and (2) ovum in subject and sperm in object position (i.e. 'the ovum absorbs the sperm'). Such sentences are typically found in the third paragraph of the original text (barring any change in the course of reproduction). In addition, sentences describing movement on the part of the sperm or ovum were also coded according to whether each of these cells were depicted as actively travelling or being passively transported. Such sentences are found in the first two paragraphs of the original text.

Inter-rater agreement of coding was checked by computing Cohen's kappa based on comparisons of 10 transcripts (13.3% of the corpus) coded by two independent persons. Kappa values were very high (.79 for verb type, .83 and .86 for subject type, .95 for interaction sentences, and .74 for navigation sentences).

The following proportions were calculated for the original text and for each reproductive generation: proportion of sentences with action verbs; proportion of sentences with action verbs where the subject is a thing; proportion of sentences with action verbs where the subject is a sexual cell; proportion of sentences depicting sperm-ovum interaction where the sperm is depicted as dominant; and proportion of sentences depicting active travel in sperm and ovum. Changes (predicted increases or decreases of proportions) were analysed with $2 \times 2 \times 4$ repeated-measures ANOVAs with gender and sex-role orientation as between-participants factors and reproductive generation as a within-participants factor with four levels (generations 1-4). In addition, since the relevant proportions in the original text are constants, all first-generation reproductions were compared with the original text using planned *t* tests.

Results

Sex-role inventory scores

Mean sex-role orientation scores (on a scale of 1-6, 1 being liberal and 6 being conservative) differed slightly according to gender (male-liberal: 1.35 (SD = .15); male-conservative: 2.13 (SD = .34); female-liberal: 1.35 (SD = .14); female-conservative: 1.91 (SD = .28)). In order to check for possible interactions between these two factors, scores were subjected to a 2×2 ANOVA with gender and sex-role orientation as between-participants factors. The ANOVA revealed only a significant main effect of sex-role orientation ($F(1, 71) = 135.36, p < .0001$). The main effect of gender and the interaction did not reach significance (gender: $F(1, 71) = 3.49, p = .066$; interaction: $F(1, 71) = 3.55, p = .064$). Therefore, the factors can be considered as unrelated.

Word and sentence count

In a first step, word and sentence counts were analysed according to the scheme described in the preceding section. The $2 \times 2 \times 4$ repeated-measures ANOVA revealed significant main effects of reproductive generation on both word ($F(3, 36) = 31.05$, $p < .0001$) and sentence count ($F(3, 36) = 24.03$, $p < .0001$). The t tests also revealed significant differences for each of these measures between the original text and the first generation (word count: $t(19) = -10.96$, $p < .0001$; sentence count: $t(19) = -8.14$, $p < .0001$). Repeated measures contrasts revealed that for word count, all generations (1–4) significantly differed from each other, whereas for sentence count, generation 1 was significantly different from generations 2–4. Results are shown in Table 1.

Table 1. Word and sentence count by reproductive generation

	Generation				
	0	1	2	3	4
Word count					
<i>M</i>	290 ^a	182.7 ^a	144.4 ^a	126.5 ^a	107
SD	—	43.8	30.8	23.9	21
Sentence count					
<i>M</i>	29 ^a	21.5 ^a	17	15.4	13.7
SD	—	4.2	3.9	3.5	2.9

Note. Proportions with superscripts are significantly larger (at $p < .05$) than corresponding proportions from subsequent generations.

Personification

Descriptive statistics for the variables measuring personification are shown in Table 2.

Table 2. Mean proportion (SDs in parentheses) of personification variables by generation

	Generation				
	0	1	2	3	4
Personification					
Action verbs	.66	.63 (.1)	.75 (.1)	.7 (.13)	.72 (.14)
Things	.6 ^a	.72 ^a (.11)	.8 ^a (.1)	.85 (.14)	.84 (.12)
Sexual cells	.56 ^a	.7 (.21)	.64 (.2)	.69 (.12)	.66 (.17)

Note. Proportions with superscripts are significantly smaller (at $p < .05$) than corresponding proportions from subsequent generations.

For action verbs, none of the factors reached significance (gender: $F(1, 12) = .24$, $p = .632$; sex-role orientation: $F(1, 12) = .02$, $p = .900$; generation: $F(3, 36) = 1.20$, $p = .324$). The t test also did not reach significance ($t(19) = -1.00$, $p = .163$). For things in the subject position, proportions increased significantly from the original to the first generation ($t(19) = 4.58$, $p < .0001$) and over the first to the fourth generation ($F(3, 36) = 7.09$, $p = .001$). This proportion was not affected by gender ($F(1, 12) = .73$, $p = .409$) or sex-role orientation ($F(1, 12) = .69$, $p = .423$). Repeated measures contrasts indicated that the generation effect was located between generations 1, 2 and 3. For sexual cells, proportions increased significantly from the original to the first generation ($t(19) = 3.10$, $p = .003$). There was no difference between proportions from the first to the fourth generations ($F(3, 36) = .42$, $p = .743$). Proportions were not affected by gender ($F(1, 12) = .29$, $p = .602$) or sex-role orientation ($F(1, 12) = .02$, $p = .888$).

Stereotyping

The proportion of sentences with the sperm in the subject and the ovum in the object increased from the original to the first generation ($t(18) = 6.22$, $p < .0001$). There were no differences in proportions from subsequent generations ($F(3, 24) = .83$, $p = .493$). This proportion was not affected by gender ($F(1, 8) = .18$, $p = .679$) or sex-role orientation ($F(1, 8) = .55$, $p = .48$). The proportion of sentences where the sperm was described as actively travelling also increased from the original to the first generation ($t(19) = 3.66$, $p = .001$), as well as over the first to the fourth generation ($F(3, 36) = 8.83$, $p < .0001$). This proportion was not affected by gender ($F(1, 12) = .64$, $p = .441$) or sex-role orientation ($F(1, 12) = .29$, $p = .598$). Repeated measures contrasts indicated that the significant increase was located between generations 1 and 2. These results are shown in Fig. 2.

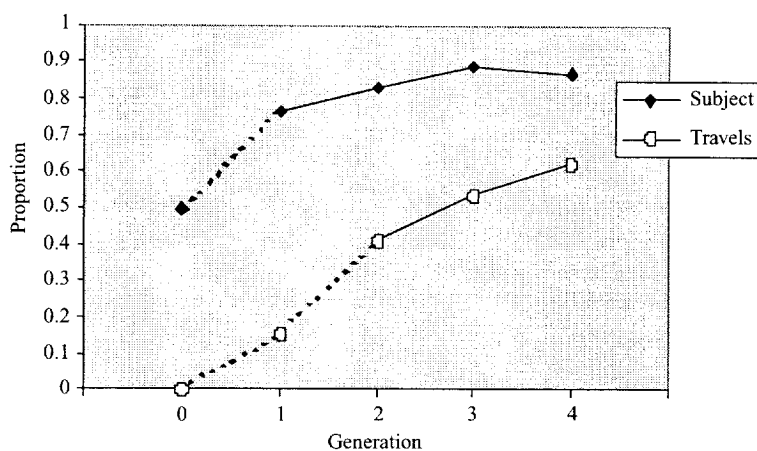


Figure 2. Mean proportions by generation of sentences with (1) sperm in the subject position, and (2) sperm described as actively travelling. Points joined by broken lines indicate proportions significantly different from each other at $p < .05$.

The proportion of sentences where the ovum was described as actively travelling did not change from the original to the first generation ($t(19) = -.942, p = .179$); there was also no effect of generation from the first to the fourth generations ($F(3, 24) = 2.73, p = .066$). There was, however, an effect of gender on these proportions ($F(1, 8) = 15.25, p = .005$), with proportions from reproductions produced by male participants being higher. This is shown in Table 3. Also, the interaction between sex-role orientation and generation was significant ($F(3, 24) = 3.66, p = .026$). *Post hoc* tests (Tukey's HSD) indicated that the effect consisted of a significant increase of this proportion for reproductions of conservative participants between generations 1 and 2.

Table 3. Mean proportion (SDs in parentheses) by generation of sentences with ovum described as actively travelling for male and female participants

	Generation				
	0	1	2	3	4
Male	.25	.31 (.40)	.60 (.25)	.67 (.31)	1.00 (.00)
Female	.25	.14 (.21)	.26 (.38)	.15 (.35)	.22 (.36)
Overall	.25	.19 (.28)	.35 (.38)	.31 (.41)	.46 (.47)

Discussion

The discussion focuses first on summarizing and discussing results, then on possible constraints on interpretation, and finally on general theoretical considerations.

In the course of serial reproduction, the text was radically shortened. The word count decreased by more than 60 % between the original and the fourth reproductive generation. However, the sentence count decreased only by half. Thus, the information in the texts does not simply decay, but retains a certain core structure, or 'gist'. This effect was also reported by Bartlett (1932).

Concerning the personification hypothesis, evidence was found for personification in the form of substantial and consistent changes in subject type. The proportion of things in the subject position of sentences increased; this is consistent with the hypothesis that personification implies a schema of object causation. Second, the proportion of sentences with one of the sexual cells (sperm and ovum) in the subject position increased in relation to the proportion of sentences with other things in the subject position. This is also consistent with expectations: sentences focus increasingly on sperm and ovum as actors in the reproductive process. The proportion of action verbs did not increase over reproductive generations as expected. This could be explained plausibly by the 'gist' phenomenon mentioned above: as central elements of a sentence, verbs are possibly more likely to be accurately retained and are therefore less susceptible to transformation.

Concerning the stereotyping hypothesis, for sentences describing an interaction between sperm and ovum, the sperm was more often described in a dominant role than the ovum. Also, the sperm was increasingly depicted as actively travelling to the meeting place, whereas the corresponding proportions did not vary for the ovum, remaining at the relatively low level (approximately .25) of the original text. The effect (shown in Table 3) of gender on the description of the ovum as actively travelling is difficult to explain. First, it was not predicted. Second, the small number of male participants makes interpretation difficult. Again, memory effects may play a role here. It may also be the case that men simply attribute higher levels of activity to both sperm and ovum. However, if this were the case, then one would have expected a similar effect of gender on personification and on sex-role stereotyping of the sperm. Thus, this result cannot be explained. Overall, however, the data are consistent with the expected projection of stereotypical attributes onto the sperm and ovum.

Contrary to expectations, sex-role orientation had no consistent effects on stereotyping. This is very probably because participants (psychology undergraduates) all had very low scores indicating liberal orientations. A replication with participants from another population seems to be necessary before drawing any conclusions.

In general, the issue of memory effects deserves some discussion. Accurate retention of the text interferes with the transformation phenomena one is trying to produce. Moreover, retention is easier in later generations, when the texts are shorter and more compact. This explains the fact that for many of the variables measured, no significant variations occurred from the second to the fourth generations. However, despite the operation of these memory effects, effects of personification and sex-role stereotyping were clearly demonstrated.

Thus, taken together, results replicate and complement earlier research on the SR of conception (Bangerter & Lehmann, 1997; Wagner *et al.*, 1995). More generally, the question arises to what degree personification is involved when other aspects of scientific discourse are transformed into common sense. Moscovici (1984, p. 41) describes the scientific mode of thinking as a '*reverse animism* that peoples the world with machines instead of living creatures'. If this is true, conventionalization of scientific representations as demonstrated in the present study might consist of 're-animating' scientific discourse for consumption by laypersons.

To conclude, it seems that serial reproduction applied within an SR framework allows one to simulate both cognitive and communicative aspects of knowledge transmitted between cultures. In this respect, it is convergent not only with SR research, but also with approaches focusing on widespread beliefs (Fraser & Gaskell, 1990) or epidemiological approaches to cultural transmission (Sperber, 1990). Further research using this method could focus on other domains or areas of representation, or on combining the method with other statistical techniques used in SR research, for example graphical techniques such as multidimensional scaling (Doise, Clémence, & Lorenzi-Cioldi, 1993). Structural change in texts over reproductive generations could thus be mapped. The important point is that the method of serial reproduction is just a technique for displaying processes of change; it must be combined with a systematic analytical procedure.

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Appendix

Original text

Fertilization typically takes place in the fallopian tube between the ovary and uterus. The ovum, which develops in the ovary, is transported to the fallopian tube. The walls of the fallopian tube are covered with ciliae. The movement of these ciliae creates a current of liquid, which transports the ovum to the place of fertilization. Muscle contractions of the walls of the fallopian tube also contribute largely to the transport of the ovum. Both the intensity of the ciliae movement and the strength of the contractions is dependent on the equilibrium between the sex hormones, oestrogen and progesterone. In this way, the ovum reaches the place of fertilization.

During copulation, the semen is deposited directly in the vagina. Contractions of the female genital tract play an especially important role in transporting the spermatozoa to the place of fertilization. Here as well, ciliae in the fallopian tube cause a current which facilitates the transport of the spermatozoa. The spermatozoa are mainly passively transported to the place of fertilization. On the way to the fallopian tube, most of the spermatozoa die off. Even though several hundred million spermatozoa are brought into the vagina, only several thousand reach the place of fertilization.

The meeting of sperm and ovum apparently takes place randomly. It is thus not the case that the spermatozoa have a sense of direction, or that the ovum somehow chemically attract the spermatozoa. The first contact takes place through an attachment reaction that is caused by substances on the surface of the egg and sperm. One sperm must penetrate through the membrane layers into the ovum. This is made possible by a local dissolution of the membrane layers by so-called lysines, which probably come from the head of the sperm. Only then does the fusion of the ovum and sperm take place. Immediately after the fusion, other processes take place, which lead, among other things, to a hardening of the ovum membrane. The modified membrane prevents further attachment of sperm.

Sample fourth-generation reproduction (female, liberal, 140 words in German)

The egg lies between the ovary and the fallopian tube. It is brought to the place of fertilization by muscle contractions and ciliae. The fallopian tube is filled with liquid, which facilitates transport. This mechanism only functions when the hormones responsible for it are in equilibrium.

Through copulation, the sperm arrive directly in the vagina and move from there into the fallopian tube. They are not chemically attracted by the egg cell. Of millions of sperm, only thousands reach the fallopian tube. The sperm that arrives first at the egg secretes a chemical substance that allows it to come into the egg. Then it secretes a chemical substance from the cell membrane that keeps other sperm from getting into the egg. Only then does actual fertilization take place. The egg then somehow reaches the uterus.

Sample fourth-generation reproduction (male, conservative, 93 words in German)

In fertilization, the egg reaches the uterus through the ovary and the fallopian tube. This takes place through muscle contractions and flagellae movements, which are triggered by the hormones oestrogen and testosterone.

The sperm is deposited in the vagina in sexual intercourse. Of initially several million sperm, only thousands reach the ovum. They move themselves by flagellae movements in the direction of the egg.

Lysin contained in the head of the sperm makes the egg membrane penetrable for a sperm. Just after fertilization takes place, the egg membranes changes to [illegible word] and becomes impenetrable for other sperm. The meeting of sperm and ovum is random.