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Answering Attitudinal Questions: Modelling the Response Process Underlying Contrastive Questions

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SUMMARY

We analyse reaction time distributions and responses for attitudinal survey questions, which were part of a self-administered questionnaire about medical and ethical issues. Two contrastive versions of each question were asked, whether an issue should be forbidden or whether the government should allow it. Logically, the answers to these contrastive questions should oppose, but numerous investigations have shown that they result in the so-called *forbid/allow asymmetry*: respondents tend to rather say 'no' to both questions. We present a mathematical model, based on point process theory, which formalises attitude representations in memory and different stages in the response process. The data of the allow questions are used for parameter estimation, while the forbid data are used to test the predictive power of different model versions. The result is a model that describes the cognitive processes underlying the asymmetry. It indicates that the forbid/allow asymmetry is caused by the use of an increased response threshold in forbid answers, and that the asymmetry size varies due to both respondent characteristics and the issue at hand. This model is capable of simultaneously predicting the asymmetry in the reaction time distributions and in the response scores for the answering categories. Copyright © 2007 John Wiley & Sons, Ltd.

INTRODUCTION

Many psychologists and linguists have studied answering in surveys and proposed models of question answering for this standardised and rather restrained type of communication (Clark & Schober, 1992; Houtkoop, 2000; Sudman, Bradburn, & Schwarz, 1996; Tourangeau, Rips, & Rasinski, 2000). Answers to attitude questions in surveys are influenced not only by the attitude or opinion that the question focuses on, but also by many characteristics of the communicative context, such as the question wording.

Various frameworks have been proposed to describe the processes of question answering and to provide some unifying framework to describe and explain wording effects and response effects. Generally, it is assumed that respondents can answer attitude questions without having a stack of stored opinions. The model of Tourangeau et al. (2000) portrays a question response process that includes four stages: (1) Interpretation of the question, (2)

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Retrieval from memory, (3) Formation of a judgment (by integration of the information retrieved), and (4) Mapping the judgment onto the pre-coded response options. Each of these components can give rise to response effects stemming from different psychological mechanisms. For example, respondents may differ in their construal of the object of the question, they can make incorrect inferences based on what they retrieve, or map their answers onto an inappropriate response category.

Previous research (Holleman, 1999a, 2000) demonstrates that it is also very revealing to distinguish two stages instead of four; one acquisition stage of comprehension and retrieval (or attitude formation), and one answering stage of translating the judgment into the response options. To distinguish two stages in the response process does not only make them measurable; it is of practical importance for questionnaire design as well: if a wording effect arises in the first stage, the implication would be that the question measured an attitude not intended by the questionnaire designer. So the question would be invalid. However, if a wording effect arises in the second stage of the response process, the question did measure the attitude the researcher intended to measure, but the translation of this attitude into a response option is distorted. Hence, the interpretation of the answers that were obtained back into the attitude the researcher intended to measure is likely to be invalid.

This paper aims to develop and test a mathematical model of this two-stage response process: the stage of acquisition, and the stage of question answering. The answering stage incorporates both judgment and response mapping in Tourangeau et al.'s sense. In our model, one possible outcome of judgment includes the attempt at additional retrieval. The data that are used to test this model are response latencies obtained for contrastive questions containing the verbs 'forbid' or 'allow' and response per cent for yes/not forbid and yes/not allow. The mathematical model of the memory processes that underlie the response process will make use of the Memory Chain Model, a neurobiologically inspired mathematical model of memory encoding, forgetting, retrieval and recall.

The Memory Chain Model has been successfully applied to several hundreds of data sets obtained from memory retention experiments, including learning and forgetting curves for normal subjects, data of different types of amnesia (Murre, Meeter, & Chessa, in press), and data on the proven recall of advertisements (Chessa & Murre, 2001; Chessa & Murre, in press; Murre & Chessa, 2002). (See for other applications: Chessa & Murre, 2004; Janssen, Chessa, & Murre, 2005). In the current paper, we will extend the model in two respects: (1) the representation of attitudes in memory, and (2) the response process, that is, the process that maps the retrieved information about a question on the answer categories. The objective of this study is to investigate whether we can use the refined memory model to describe the response process underlying the forbid/allow asymmetry.

As the new mathematical model of the response process will be applied to questionnaire data, gathered with contrastive questions using the verbs 'forbid' or 'allow', some background information about the response process underlying contrastive questions is useful. Much is already known about this, so these questions form an excellent starting point for the development of a mathematical model of the response process.

The *forbid/allow asymmetry* is a famous and well-investigated example of a wording effect in survey research, an effect that was first 'discovered' by Rugg (1941). In the advice books, questionnaire designers are usually recommended to balance their questions in order to avoid answering tendencies: they should vary the perspective of their questions in the questionnaire by using negative as well as positive questions. This advice suggests that the answers to a positive question will not differ from the answers to the equivalent

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opposite question. Rugg's research (on the attitudes towards public speeches against democracy) shows that this presupposition does not hold: when answering the allow question, many respondents seemed to be against public speeches against democracy (75% answered 'no' to the allow question), whereas respondents seemed much more positive about these speeches when answering the equivalent forbid question (only 54% answered 'yes' to the equivalent forbid question). Since the 1940's, this wording effect has been widely investigated (Bishop, Hippler, Schwarz, & Strack, 1988; Hippler & Schwarz, 1986; Holleman, 1999a; Holleman, 2000; Krosnick & Schuman, 1988; Reuband, 2000; Schuman & Presser, 1981; Waterplas, Billiet, & Loosveldt, 1988). The effect is shown to vary between questions, but across questions a consistent pattern is shown: a meta-analysis of 52 forbid/allow questions administered in different countries and languages (Holleman, 1999b, 2000) showed a mean difference between 'not forbid' and 'yes allow' of 14.2% points, and a standard deviation of 9.85.

A number of explanations for the asymmetry have been put forward and were tested. Schuman and Presser (1981) suggested that the connotations of 'forbidding' as well as 'allowing' are extreme. For many respondents to forbid is too harsh to be able to endorse it, whereas to allow seems to encourage a deviant behaviour—hence a tendency to answer 'no' to both questions. Hippler and Schwarz (1986) as well as Holleman (2000) tested this hypothesis and confirmed that 'not to forbid' (or 'not to allow') seems to be a more moderate standpoint than 'to allow' (or 'to forbid', respectively). In addition, experiments conducted by Holleman (2006) suggested that 'to forbid' is more extreme than 'to allow', as forbidding unambiguously refers to a restricting action, whereas allowing is ambiguous: it can either refer to an act of removing some barrier, or refer to an act of not doing anything, letting things go.[1] A mathematical model of the response process should account for differences in response latencies between different versions of the same question.

This paper is organised as follows. In the Section on The Attitude Survey, we will describe the survey experiment and the data with respect to the forbid/allow asymmetry, which consist of acquisition and answering times and the per cent of responses in favour of allowing and forbidding for every topic.

In the Section on A Model for the Response Process, we will formalise attitudes in terms of *point processes*, which form the mathematical basis of elements in memory in the existing Memory Chain Model. Next, we will formalise the response process for the forbid/allow questions, which we will use to derive: (1) probability distributions of both acquisition time and answering time, and (2) expressions for the expected response per cent in favour of forbidding and allowing.

In the Section on Model Validation, we will validate the response process model with the data. First, we will estimate the model parameters from the data for the allow versions of the questions. Next, we will fit the acquisition and answering time distributions obtained in this way to the empirical distributions of the forbid questions. We will do the same with the response probabilities of forbidding. In other words, we will answer the following question: Is the response process model able to predict the acquisition and answering time distributions, and the response probabilities of the forbid questions, given the estimated

[1]Other experiments focus on the extent to which the wording effect can be explained by the concept of 'attitude strength'. Are respondents who hold weak attitudes (e.g. who do not feel involved with the issue at stake, or who hold moderate or ambivalent attitudes) more susceptible to superficial characteristics of the question wording such as the use of forbid/allow? There does seem to be a relation, but the results are not unequivocal. In the current paper, this explanation of the wording effect will be left aside.

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distributions from the allow data? The results will be discussed in the Section on Discussion.

THE ATTITUDE SURVEY

The experiment

The mathematical model of the response process was further developed and tested using the data gathered in an existing experiment (Holleman, 2005). The data consist of the response per cent to seven forbid/allow questions, and the response latencies to these seven questions.

A computer-assisted self-administered questionnaire was used. Latencies are measured separately for two stages of the response process: the time spent on the acquisition stage (reading and interpretation, attitude retrieval) starts when a question becomes visible on screen and stops as soon as the respondent presses a button in order to get the answering options on screen. This starts the time measurement of the last stage of the response process, the mapping of a judgment into a response. The time measurement of this second stage stops as soon as the respondent provides a response. Subsequently, the respondent pushes the spacebar to get the next question on screen. By using this method, the response latencies can be linked more closely to processes underlying responses that are assumed theoretically.

The latency data were collected with a questionnaire that consisted of various questions, including several questions for which a forbid/allow question wording was manipulated. A survey about new medical technologies and medical ethics (cosmetic surgery, IVF, euthanasia, etc.) was developed, based on newspaper articles with recent discussions of these issues. The questionnaire started with three questions to practice with the machine. After that, there was a short pause to ask questions to the researcher. Then the actual survey started, which consisted of 34 questions about five issues: cosmetic plastic surgery, euthanasia, abortion, genetic technology, and surrogate motherhood. Each issue started with a brief introduction, followed by about six or seven questions: one or two forbid/allow questions and several filler questions. The seven forbid/allow questions used can be found in Appendix A.

The questionnaire was administered by laptop to 89 5th grade secondary school-pupils (about 16-year-old). The software package E-prime was used to measure acquisition and answering times. Two versions of the questionnaire were made: in Version 1 the manipulated questions were worded in an allow format, in Version 2 a forbid wording was used for equivalent questions. Versions were randomised across respondents.

Data

The data obtained from the separate measurement of acquisition and answering times were used to derive (cumulative) empirical distributions for every survey question. First, a preliminary multivariate outlier analysis was conducted to clean the reaction time data from outliers (Fazio, 1990) cf. a proposal by Bollen (1989, pp. 23–31). Second, it was analysed whether certain respondents had answering and acquisition times that were distinctly different from those of the other respondents. This resulted in the removal from the dataset of four cases. The new dataset, now containing the answering and acquisition times of 85 respondents, was analysed on outliers. It turned out that 31 acquisition or

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Table 1. The answers to the manipulated forbid/allow questions ($N = 85$)

	Answers	
Question	Not allow (%)	Yes forbid (%)
Plastic surgery	7.7	4.3
Euthanasia 1	53.8	32.6
Euthanasia 2	28.2	28.3
Abortion	15.4	8.7
Gen-technology 1	28.2	15.2
Gen-technology 2	79.5	67.4
Surrogate motherhood	17.9	28.3

Euthanasia 1 = lack of clarity of mind.
Euthanasia 2 = mental suffering.
Gen-technology 1 = genetic disorders.
Gen-technology 2 = choice of sex of unborn children.

answering times were notably different from the others. They were replaced by the mean for that variable.

Table 1 shows the per cent of answers in favour of 'not allow' and 'yes forbid' for the seven questions. The data show that the per cent of responses for 'yes forbid' is almost always below the figure for 'not allow' responses, with the largest difference ($p < 0.05$) arising for the first question on euthanasia. The effect is shown to vary between questions: the question on surrogate motherhood even shows an asymmetry in an opposite direction. Such a variation is a consistent finding in all forbid/allow research (Holleman, 1999b).

Acquisition time and answering time distributions were measured for each of the four possible answers: 'yes allow', 'not allow', 'yes forbid', and 'not forbid'. The sample means and standard deviations for the empirical acquisition time and answering time distributions are shown in Tables 2 and 3, respectively. For each question, we analysed the observed reaction time data.[2] For *Yes allow* versus *Not forbid* the acquisition time distributions do not differ significantly, nor do the answering times. For *Not allow* versus *Yes forbid* no significant differences were found for the acquisition time distributions. However, significant differences for the answering time distributions were found for the first question

Table 2. Sample means and standard deviations, within brackets, of the acquisition times (in seconds) for each of the four answering options for the seven questions

Question	Yes allow	Not allow	Not forbid	Yes forbid
Plastic surgery	4.895 (3.588)		4.522 (2.209)	
Euthanasia 1	7.767 (4.171)	5.131 (1.347)	8.244 (6.567)	5.632 (2.096)
Euthanasia 2	7.005 (8.088)	5.391 (2.651)	6.231 (4.098)	6.288 (3.917)
Abortion	7.996 (4.816)		9.138 (6.255)	
Gen-technology 1	7.270 (4.559)	7.731 (3.804)	7.897 (5.144)	5.716 (3.437)
Gen-technology 2	4.916 (2.421)	4.865 (2.769)	5.252 (2.491)	4.340 (2.621)
Surrogate motherhood	14.791 (7.272)	18.005 (6.563)	15.972 (7.041)	14.201 (9.509)

A blank cell means that the sample statistics were not calculated because of a limited sample size.

[2]For this analysis, we carried out a series of two-sample Kolmogorov-Smirnov tests for both acquisition times and answering times and tested whether pairs of empirical distributions are samples of the same probability distribution.

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Table 3. Sample means and standard deviations, within brackets, of the answering times (in seconds) for each of the four answering options for the seven questions

Question	Yes allow	Not allow	Not forbid	Yes forbid
Plastic surgery	1.355 (0.670)		1.285 (0.913)	
Euthanasia 1	2.995 (3.173)	3.339 (7.076)	2.802 (2.470)	4.383 (3.415)
Euthanasia 2	1.222 (0.684)	1.866 (1.732)	1.308 (1.133)	3.670 (3.322)
Abortion	2.053 (2.385)		1.607 (1.487)	
Gen-technology 1	1.690 (1.382)	3.423 (4.877)	1.853 (1.062)	2.194 (0.705)
Gen-technology 2	1.311 (1.031)	1.058 (0.559)	1.414 (0.820)	2.041 (1.116)
Surrogate motherhood	1.805 (1.720)	2.428 (1.949)	1.736 (1.396)	3.960 (3.020)

A blank cell means that the sample statistics were not calculated because of a limited sample size.

on euthanasia and for the second question on gen-technology ($p < 0.05$). The answering times for both questions are systematically larger in the case of the 'yes forbid' answers compared to 'not allow'. The test results tell us that a forbid/allow asymmetry arises only during the answering phase, where it is only found when comparing the 'yes forbid' and 'not allow' answers. These test results are in close agreement with findings in Holleman (2005).

A MODEL FOR THE RESPONSE PROCESS

Formalisation of attitudes

In the Memory Chain Model, memory is modeled as a point process (Daley & Vere-Jones, 1988; Diggle, 1983; Stoyan, Kendall, & Mecke, 1987). A point process is a probabilistic model for the occurrence of 'events' in space and/or time, which are represented as 'points'. In the neurosciences, point processes have been used to describe time-series of firing neurons (Abeles, 1991). The variable of interest in the Memory Chain Model is the strength of a memory representation of some stored item, which is quantified as the number of 'points' in memory through time.[3]

The survey data do not only contain information about the strength of an attitude, but also about its evaluation. According to Fazio (1990, 1995), 'an attitude is represented in memory as an association between an object and a summary evaluation of that object. The strength of the association between the object and the summary evaluation determines the accessibility of the attitude and hence the likelihood that the summary evaluation will be activated in memory [...]'. The strength of an association between an object and its evaluation is already captured by a point process in terms of the number of points or critical features of a memory representation that are cued, for instance, by a survey question. However, the Memory Chain Model does not contain a formalisation of the summary evaluation of an attitude. In order to achieve this in the new model, we mark every point with a binary variable. Every point or 'attitude feature' either has a positive or negative evaluation associated with it. In point process theory, a model of this kind is called a *marked point process* (Stoyan et al., 1987).

[3]In a psychological sense, the 'points' could be conceived of as 'critical features' of a memory representation (Murdock, 1974). In the Memory Chain Model, these 'points' could also be linked to neural processes on different time scales (McGaugh, 2000).

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Response process model

The Memory Chain Model gives an abstract formalisation of the neurobiological processes underlying memory and retention. A memory is formed at initial exposure or learning of an item. Within a survey context, this is the time at which information about the topic of a survey question was encoded initially. We will now summarise the stages in the Memory Chain Model between initial encoding and recall or response, which we subsequently use for developing a model for the response process in forbid/allow questions.

Encoding. At the end of item exposure, a memory reaches a strength or *intensity* μ, which is equal to the mean number of features in a memory representation. In the case of attitudes, the initial encoding μ is the sum of the intensities of positive and negative evaluations. We assume that evaluations of different attitude features are identically and independently distributed (in probabilistic terms). 'Identical' means that evaluations are independent of both the location of attitude features in memory and of the time at which features are activated.

Storage. After item exposure, forgetting usually takes place, which in our model is described as a point process with an intensity function, which describes whether short-term memories will consolidate into longer-term representations in different parts of the brain or whether the initially encoded memory will be lost rapidly.

Retrieval. When retrieval is attempted at a survey question, a cue will be used to access a target item. A subspace of the brain will be searched for memory representations. The number of retrieved features depends on the effectiveness of a retrieval cue.

Recall. Our model includes a fourth stage, which can be considered a decision process that relates recall to retrieval. The number of retrieved features determines whether recall will take place or not. The number of features is compared with a threshold, which is the minimum number of features required for recall. In almost all applications of the Memory Chain Model, it is assumed that recall takes place if at least one feature has been retrieved.

The retrieval and recall stages in the Memory Chain Model are the building blocks for the acquisition and answering stages within our two-stage response model. This model encompasses the following, more detailed stages (Figure 1):

1. When a question is asked, a respondent selects one or more cues from it;
2. The cues are then used in a search process, where features of a memory representation may become activated and subsequently retrieved;
3. A judgment is formed on the basis of the information retrieved;
4. If the information retrieved is considered to be sufficient, then an answer will be selected from the response categories; otherwise, a new memory search will be undertaken, which takes the respondent back to Step 2. Whether the respondent will give a definite answer depends on the recall threshold.

This process is similar to the four stages in the response process of Tourangeau et al. (2000): (1) comprehension of a question, (2) retrieval from memory, (3) integration of the information retrieved into a judgment, and (4) mapping of the judgment onto response categories. Our model permits in Step 3 a probability to engage in additional memory search and retrieval, which will be worked out at the end of this section.

We make the following assumptions with respect to memory intensity and the response threshold in the response model. The time span on which the response process takes place is in the order of seconds. Although memory may weaken on such small time scales as well, we assume that memory intensity is constant during the response process. This assumption

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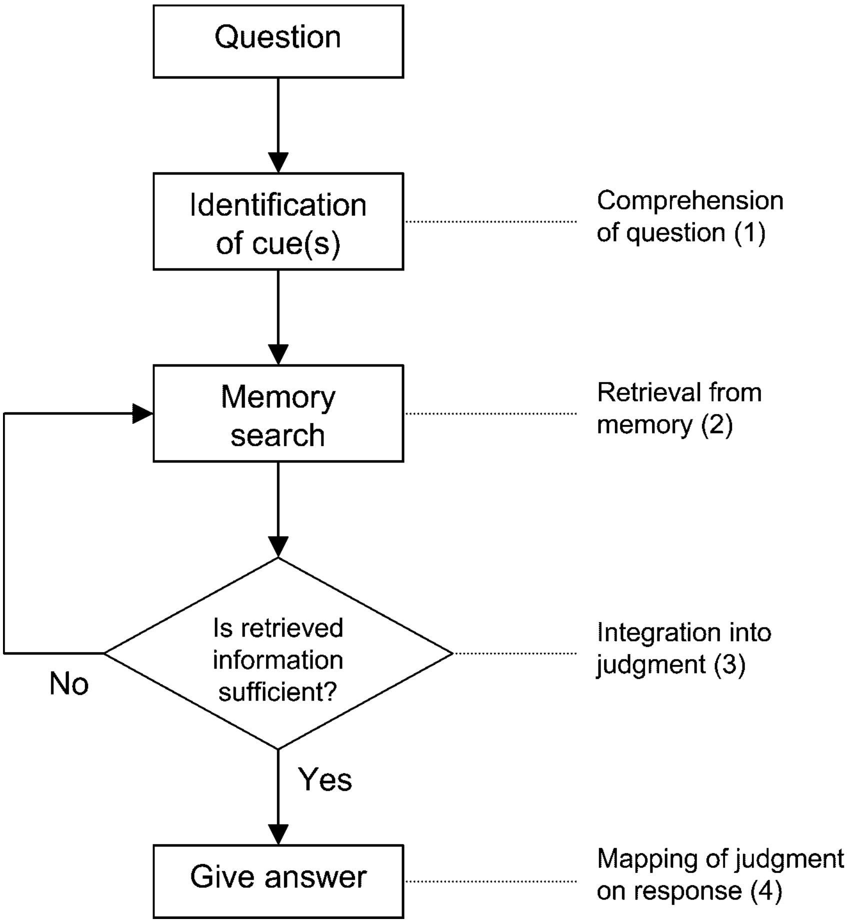

Figure 1. The response process for the Memory Chain Model in relation with Tourangeau et al.'s (2000) four-stage process (see right-hand side)

leads to a large reduction of the parameters in the original Memory Chain Model. The intensities of cued positive and negative attitude evaluations during the response process will be denoted as μ^+ and μ^-, respectively.

The data in this paper show that, for most questions, the answering time for 'yes forbid' is greater than for 'not allow'. As was discussed in Introduction Section, previous research on the mapping of judgments into a yes/no-answer on forbid/allow questions suggests that the answering option 'yes forbid' seems to be too extreme for many respondents to endorse (Holleman, 2000). The greater effort spent in finding this answer may be found in longer search times for retrieving additional information to support the answer 'yes forbid'.

Within the context of the Memory Chain Model, this can be translated in terms of a higher response threshold for forbid questions than for allow questions. In most applications of the Memory Chain Model to retention data, the recall or response threshold was set at the value of one retrieved memory feature. We maintain this assumption in the answering of allow questions. In the case of forbid questions, we assume that the response threshold for 'yes forbid' is increased, such that two attitude features are retrieved, which

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must both be linked with negative evaluations of that attitude. The implications of this assumption for forbid questions are the following:

1. If the first attitude feature found has a positive evaluation, then the answer will be 'no, not forbid';
2. If the first attitude feature found has a negative evaluation, then a further memory search will be carried out until a second feature will be found (as illustrated in Figure 2). If that feature has a negative evaluation, then the answer will be 'yes forbid'; otherwise, the answer will be 'not forbid'.

The response mapping processes for allow questions and forbid questions are illustrated in Figure 2, which shows a refinement of the response mapping process for forbid questions. Instead of doing an additional memory search with full certainty in Step 2 above, a respondent decides to do a second search with probability p. Although this is a simple refinement, it specifies a family of asymmetry models. The extent of the forbid/allow asymmetry can be illustrated by varying p, the chance of an additional memory search. If $p = 0$, that is, if no additional search will be carried out, then there will be no asymmetry, which means that the reaction times and the response scores will be the same for forbid questions and allow questions. This special case could be seen as a benchmark model. If $p = 1$, then the extent of the asymmetry will be maximised. It is insightful to investigate the effect of variations in p on reaction times and response scores; this will be considered in the Section on Model Predictions for Forbid Questions.

Model characteristics

The assumptions stated in the Section on Response Process Model imply mathematical expressions for the following response process characteristics, which will be used in Model Predictions for Forbid Questions Section to fit the data: (i) response probabilities, (ii) acquisition time distributions, and (iii) answering time distributions. Each of these characteristics will be described below for each of the answering options.

Response probabilities

Not allow. The first evaluation found determines the answer for allow questions so that the probability of answering 'no (not allow)' is equal to the probability of a negative evaluation, given that an attitude feature is found. This probability is equal to the ratio of the intensity of negative evaluations (μ^-) to the total intensity,[4] that is:

$$P_{na} = \frac{\mu^-}{\mu^+ + \mu^-} \tag{1}$$

Yes allow. Since there are two answering options, the probability of answering 'yes allow' is equal to $1 - P_{na}$.

Yes forbid. The situation is more complicated in this case, since an answer may be given after one or after two attitude features retrieved. If no additional memory search takes place after retrieval of the first feature with a negative evaluation, then the answering probability is equal to Equation (1) with probability $1 - p$. If a second search is carried out, the answer

[4]The details of the mathematical proof are based on the abstract theory of conditional distributions for point processes, which will be omitted here (Chessa, 1995; Daley & Vere-Jones, 1988; Stoyan et al., 1987).

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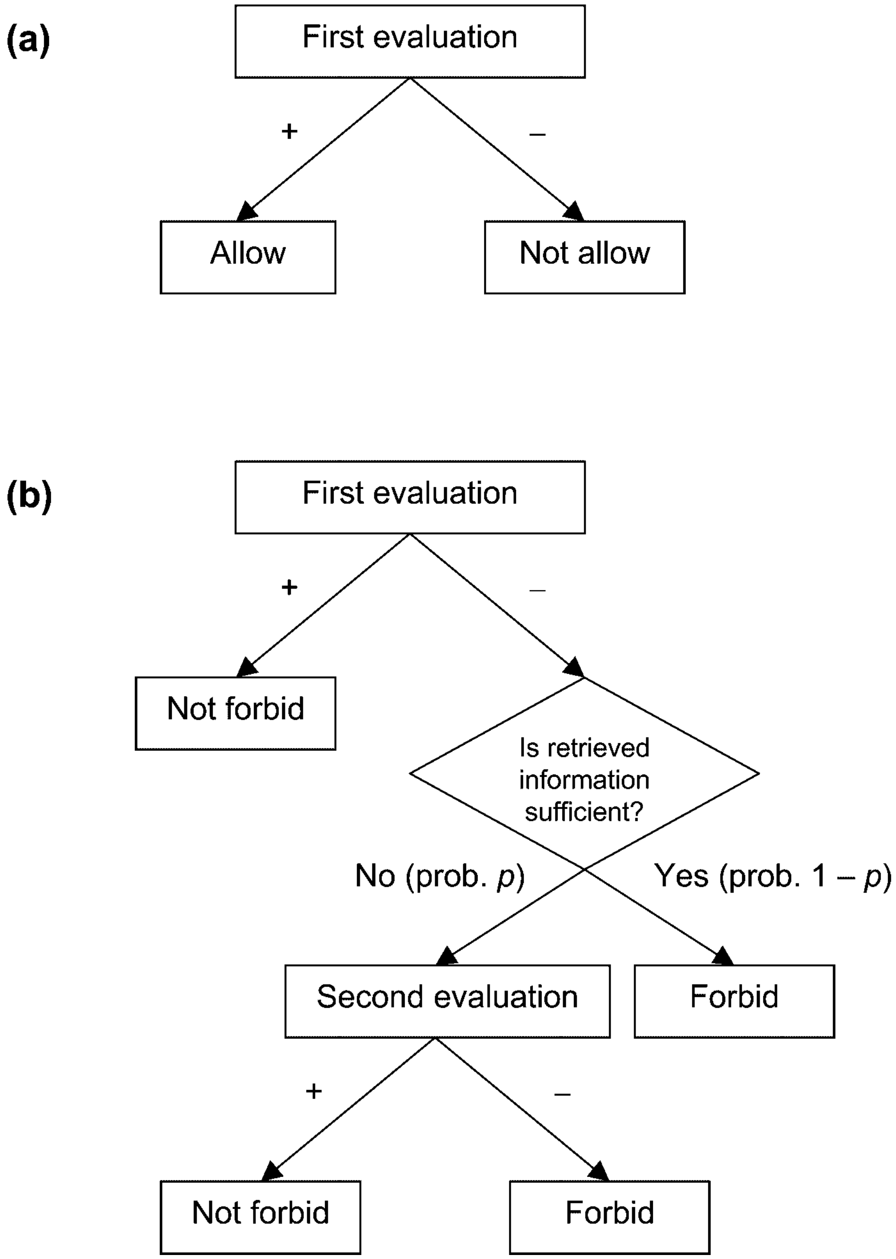

Figure 2. The response mapping phase for allow (a) and forbid questions (b)

will be 'yes (forbid)' when the second feature retrieved also has a negative evaluation. Since evaluations of different attitudes features have identical distributions, the probability that the second feature has a negative evaluation is also equal to Equation (1). We can write P_{yf} as a function of the probability of answering 'no (not allow)':

$$P_{yf} = P_{na} - pP_{na}(1 - P_{na}) \tag{2}$$

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which shows that the probability of ‘yes (forbid)’ can never be greater than the probability of answering ‘no (not allow)’. Expression (2) enables us to make direct statements about the probability of answering ‘yes forbid’, once we know the answering probability for ‘not allow’. In particular, notice that $P_{yf} = P_{na}$ when the additional memory search probability $p = 0$, while $P_{yf} = P_{na}^2$ when $p = 1$.

Acquisition time distributions
One of the main characteristics of this survey is the decomposed measurement of the total reaction time into acquisition time and answering time. In order to model both latencies, we have to make assumptions about the phasing of the response process. We define acquisition time as the time that elapses until the first memory feature is encountered during a memory search. The acquisition phase thus encompasses Stages (1) and (2) in the flow chart of Figure 1, that is, question comprehension and memory retrieval in Tourangeau et al.’s sense. Whether the information retrieved is sufficient for selecting an answer (Stages (3) and (4)), will be decided when respondents see the answering categories, after pressing a key at the end of the acquisition phase.

In order to derive probability distributions of the acquisition time for each of the two answering possibilities for allow questions and forbid questions, we assume that acquisition times are the sum of:

1. *Comprehension time*, which involves reading and interpreting a question;
2. *Memory search time*, during which cues will be used to search for attitudes.

In order to keep the derivation of the acquisition time distributions analytically tractable, we limit the number of parameters and the complexity of the comprehension time distributions. We assume that comprehension time has an exponential distribution function given by:

$$F_c(t) = 1 - \exp(-(\lambda/r)(t - kr)), \quad t \geq kr \tag{3}$$

The time-shift by the amount kr can be interpreted as a minimum acquisition time, which increases with the length r of a question, which we take equal to the number of words. The parameter $k > 0$ denotes the minimum acquisition time per word. The mean comprehension time according to this distribution is equal to $r/\lambda + kr$, where $\lambda > 0$ can be identified with the comprehension rate or speed. Pressing a key to see the response options also requires time. We do not introduce an additional parameter for the time that this action takes, but assume that the time required is accommodated in comprehension time.

The acquisition time distribution functions for each of the four answering possibilities were calculated from the convolution of comprehension time and memory search time, that is, the probability density function of the sum of the two times. The memory search time distribution functions for the four answering options will not be derived in this paper.[5] The four distribution functions of acquisition time are given below.

[5]The methods used for deriving memory search time distributions can be found in the point process literature. Memory search time is equivalent with the time elapsed between an arbitrarily chosen point and an occurrence (‘point’) of a point process. The Memory Chain Model assumes that memories are stored and activated in time according to a *Poisson point process*. *Stationary* or *homogeneous Poisson processes* with intensity μ, which are used in this paper, imply the well-known result that the time elapsed until the first occurrence of such processes has an exponential distribution with parameter μ.

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Not allow. The convolution of comprehension time and the exponential memory search time distribution gives rise to the acquisition time distribution function

$$\frac{\mu^-}{\mu^- - \lambda/r}\left(1 - e^{-\frac{\lambda}{r}(t-kr)}\right) - \frac{\lambda/r}{\mu^- - \lambda/r}\left(1 - e^{-\mu^-(t-kr)}\right), \quad t \geq kr \tag{4}$$

Yes allow. The acquisition time distribution function has the same form as Equation (4), where μ^- is replaced by μ^+:

$$\frac{\mu^+}{\mu^+ - \lambda/r}\left(1 - e^{-\frac{\lambda}{r}(t-kr)}\right) - \frac{\lambda/r}{\mu^+ - \lambda/r}\left(1 - e^{-\mu^+(t-kr)}\right), \quad t \geq kr \tag{5}$$

Yes forbid. The acquisition time distribution function for 'yes forbid' is the same as for 'not allow', which is therefore given by Equation (4).

Not forbid. In this case, the memory search time distribution is a mixture of two exponential distributions (one with parameter μ^+ and the other with parameter μ^-). This is because a 'not forbid' answer can be given in situations where the first attitude feature retrieved is positive or negative. The acquisition time distribution function therefore is a combination of the acquisition time distributions for 'yes allow' and 'not allow':

$$\begin{aligned} &P\left\{\frac{\mu^+}{\mu^+ - \lambda/r}\left(1 - e^{-\frac{\lambda}{r}(t-kr)}\right) - \frac{\lambda/r}{\mu^+ - \lambda/r}\left(1 - e^{-\mu^+(t-kr)}\right)\right\} \\ &+ (1-P)\left\{\frac{\mu^-}{\mu^- - \lambda/r}\left(1 - e^{-\frac{\lambda}{r}(t-kr)}\right) - \frac{\lambda/r}{\mu^- - \lambda/r}\left(1 - e^{-\mu^-(t-kr)}\right)\right\}, \; t \geq kr \end{aligned} \tag{6}$$

P is the 'mixing probability', which is given by:

$$P = \left(1 + \frac{\mu^-}{\mu^+ + \mu^-}p\right)^{-1} \tag{7}$$

Answering time distributions

Answering times are determined by Stages (3) and (4) of the response process in Figure 1. When respondents see the answering options, they will decide whether the information retrieved at the end of the acquisition phase is sufficient for selecting an answer. At that time, respondents have already retrieved one attitude feature in terms of our model. This implies that no additional memory searches and retrieval take place in the case of allow questions, so that only response mapping takes place.

In order to derive probability distributions of the answering time for each of the two answering possibilities for allow questions and forbid questions, we assume that answering times are composed by two components that are similar to acquisition times:

1. *Judgment time*, which involves reading the answering options, judging whether an answer can be selected, selecting the appropriate answer, and pressing a key for viewing the next question;
2. *Memory search time*, if the respondent wants to retrieve more information.

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We assume an exponential distribution function for judgment time, which has a form similar to Equation (3):

$$F_s(t) = 1 - \exp(-\alpha(t - \beta)), \quad t \geq \beta \tag{8}$$

The distribution functions of answering time for the four answering possibilities are given below.

No (not allow). As no additional memory searches will be carried out, the answering time distribution function is equal to distribution function (8).

Yes (allow). The same holds for this answering option.

Yes (forbid). An additional memory search is carried out with probability p. If no further memory search will be carried out, then the answering time will be equal to judgment time. The answering time distribution function therefore is a mixture of two distributions, which is given by:

$$(1-Q)\left(1 - e^{-\alpha(t-\beta)}\right) + Q\left\{\frac{\mu^-}{\mu^- - \alpha}\left(1 - e^{-\alpha(t-\beta)}\right) - \frac{\alpha}{\mu^- - \alpha}\left(1 - e^{-\mu^-(t-\beta)}\right)\right\}, \ t \geq \beta \tag{9}$$

Q is the (conditional) probability of answering 'yes forbid' after a second memory search. It is given by:

$$Q = \frac{\left(\frac{\mu^-}{\mu^+ + \mu^-}\right)^2 p}{\frac{\mu^-}{\mu^+ + \mu^-}(1-p) + \left(\frac{\mu^-}{\mu^+ + \mu^-}\right)^2 p} \tag{10}$$

No (not forbid). Also here we obtain a mixture of distributions. With probability P, given by Equation (7), the answer will be 'not forbid' without a further memory search. With probability $1 - P$, the same answer will be given after retrieving a second, positively evaluated attitude feature, which is the situation where the first attitude feature, retrieved at the end of the acquisition stage, has a negative evaluation (Figure 2). We obtain a distribution function, where the judgment time function (8) is weighted by P, while the distribution function that corresponds with the second memory search is weighted by $1 - P$:

$$P\left(1 - e^{-\alpha(t-\beta)}\right) + (1-P)\left\{\frac{\mu^+}{\mu^+ - \alpha}\left(1 - e^{-\alpha(t-\beta)}\right) - \frac{\alpha}{\mu^+ - \alpha}\left(1 - e^{-\mu^+(t-\beta)}\right)\right\}, \ t \geq \beta \tag{11}$$

MODEL VALIDATION

This section presents and discusses the results. The model developed in the previous sections was tested. This was done in two subsequent steps: first, the parameters were estimated based on the response scores and the observed acquisition and answering times for the allow questions (Section on Parameter Estimation With Allow Data). Then, it was tested whether the model was able to predict the response scores and the acquisition time and answering time distributions for the forbid questions (Section on Model Predictions for Forbid Questions).

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Parameter estimation with allow data

We only fitted the acquisition time and answering time distribution functions (4), (5) and (8) to the corresponding empirical distributions for 'yes allow' and 'not allow' answers. We included the response scores for 'not allow' in the fits as well, with the theoretical probabilities given by expression (1). In this way, we obtain estimates for all the parameters, with the exception of the probability p of a second memory search, which was introduced only for forbid questions. But given a value for p, we can directly fit the acquisition time and answering time distribution functions (4), (6), (9) and (11) to the corresponding empirical distributions for 'yes forbid' and 'not forbid', and compare the values for the response probability (2) for answering 'yes forbid' to the data. So, the question that will be answered in the next subsection is to what extent we can predict the distribution functions and response per cent for 'yes forbid' and 'not forbid', for different values of p, without doing additional parameter estimation.

We used 24 empirical distributions from a total of 28 distributions (7 questions, yes/not allow, acquisition times and answering times) and the 'not allow'-scores for the 7 questions in order to estimate the parameters. We left out the 'not allow'-data for the questions on plastic surgery and abortion because of small sample sizes (less than 10 'not allow'-answers on both questions). We fitted the data by imposing conditions on a number of parameters:

1. The comprehension rate λ and the minimum comprehension time per word k are assigned the same values for all the questions. We thus ascribe differences in acquisition time distributions over questions to the intensities μ^+ and μ^-, and to the number of words r;
2. We also assigned the same value to β in Equation (8) for all the questions.

In order to decide how to set α in Equation (8), we checked whether the empirical answering time distributions differ across allow questions. Although the answering sheets are the same for every question, we found differences between the two questions on euthanasia, between the two gen-technology questions, and between the question on plastic surgery and the first question on euthanasia (Kolmogorov–Smirnov two-sample test, alpha $= 0.05$). These variations could be random or may be caused by other, unknown factors. We used these findings to let α vary for three questions (plastic surgery, first euthanasia question, second gen-technology question); the values of α for the other four questions were set equal to the value for the question on plastic surgery. This yields 20 different parameter estimates for 48 distributions and 14 response per cent (over allow and forbid data).

We estimated the parameters by minimising a chi-square statistic (Berkson, 1980; Wickens, 1982).[6] The parameter values are given in Table 4. The corresponding fitted

[6]In order to use chi-square statistics, we had to subdivide the time domain into time bins. We used time bins of one second for acquisition time and calculated the empirical probability mass for every time bin. The time bins for the answering time distributions were based on the percentile values of the time bins defined for the empirical acquisition time distributions. For every time bin of the acquisition and answering time distributions of yes and not allow responses we defined a Neyman reduced chi-square statistic, which differs from the (classical) Pearson statistic in the use of the observed number of responses in a time bin instead of the expected value in the denominator. Pearson's chi-square statistic has the problem that its denominator often returned the value zero. We also defined a Neyman chi-square statistic for the yes and not allow response per cent of every question. The chi-square statistic minimised is equal to the sum of the chi-square statistics over all the distributions and response per cent for yes and not allow of the seven questions. We minimised the sum chi-square statistic because the values of certain parameters are shared over distributions and questions.

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Table 4. Parameter estimates based on the data of the allow questions

	Parameter values						
Question	μ^+	μ^-	r	λ	k	α	β
Plastic surgery	0.413	0.034	10	13.532	0.138	1.673	0.778
Euthanasia 1	0.154	0.218	17	Same	Same	0.974	Same
Euthanasia 2	0.263	0.113	11	Same	Same	1.673	Same
Abortion	0.201	0.036	17	Same	Same	1.673	Same
Gen-technology 1	0.251	0.109	15	Same	Same	1.673	Same
Gen-technology 2	0.991	3.903	16	Same	Same	2.134	Same
Surrogate motherhood	0.209	0.048	43	Same	Same	1.673	Same

distribution functions for 'yes allow' and 'not allow' are shown in Figures 3 and 4, for acquisition and answering times, respectively, per question. The value of the minimised Neyman chi-square statistic is 240.7 ($df = 207$). The fitted distributions and response probabilities are not rejected at alpha = 0.05.

The values of the intensities μ^+ and μ^- denote the expected number of attitude features with positive and negative evaluations, respectively, that are retrieved per second. The larger the intensity, the steeper the corresponding acquisition time distribution. The values in Table 4 show that both intensities are small for the questions on abortion and surrogate motherhood. Assuming that the question was clear and understandable to the respondents, the intensities tell us that the respondents did not have much information about the topic at the time that these questions were asked.

At the other end, we see that both intensities have large values for the second question on gen-technology. But the value of μ^- is almost four times larger than μ^+, which explains why nearly 80% of the respondents are expected to answer that the choice of the sex of unborn children should not be allowed, as can be derived from expression (1).

We finally note the large relative difference between the two intensities for the question on plastic surgery and, to a lesser extent, for the question on abortion. This difference implies an outspoken opinion in favour of allowing and not forbidding, which also follows from the data and the model results in Table 6, as μ^+ is greater than μ^-.

Model predictions for forbid questions

We substituted the parameter values listed in Table 4 in the acquisition time and answering time distribution functions of the 'yes forbid' and 'not forbid' answers, which we fitted to the corresponding empirical distributions. We also calculated the response probabilities of 'yes forbid'.

It may be hypothesised that not all the respondents make the same choice with respect to performing an additional memory search in forbid questions. We varied p manually between 0 and 1 in order to study this hypothesis. For instance, $p = 0.2$ means that an average of 20% of the respondents will decide to do an additional memory search. We considered six hypotheses about the additional memory search probability p, namely, $p = 0$, 0.2, 0.4, 0.6, 0.8, and 1. We considered the case $p = 0$ as a benchmark, which is the case where the acquisition time and answering time distributions, and the response probabilities for allow questions and forbid questions, are the same. In this case, there is no forbid/allow asymmetry.

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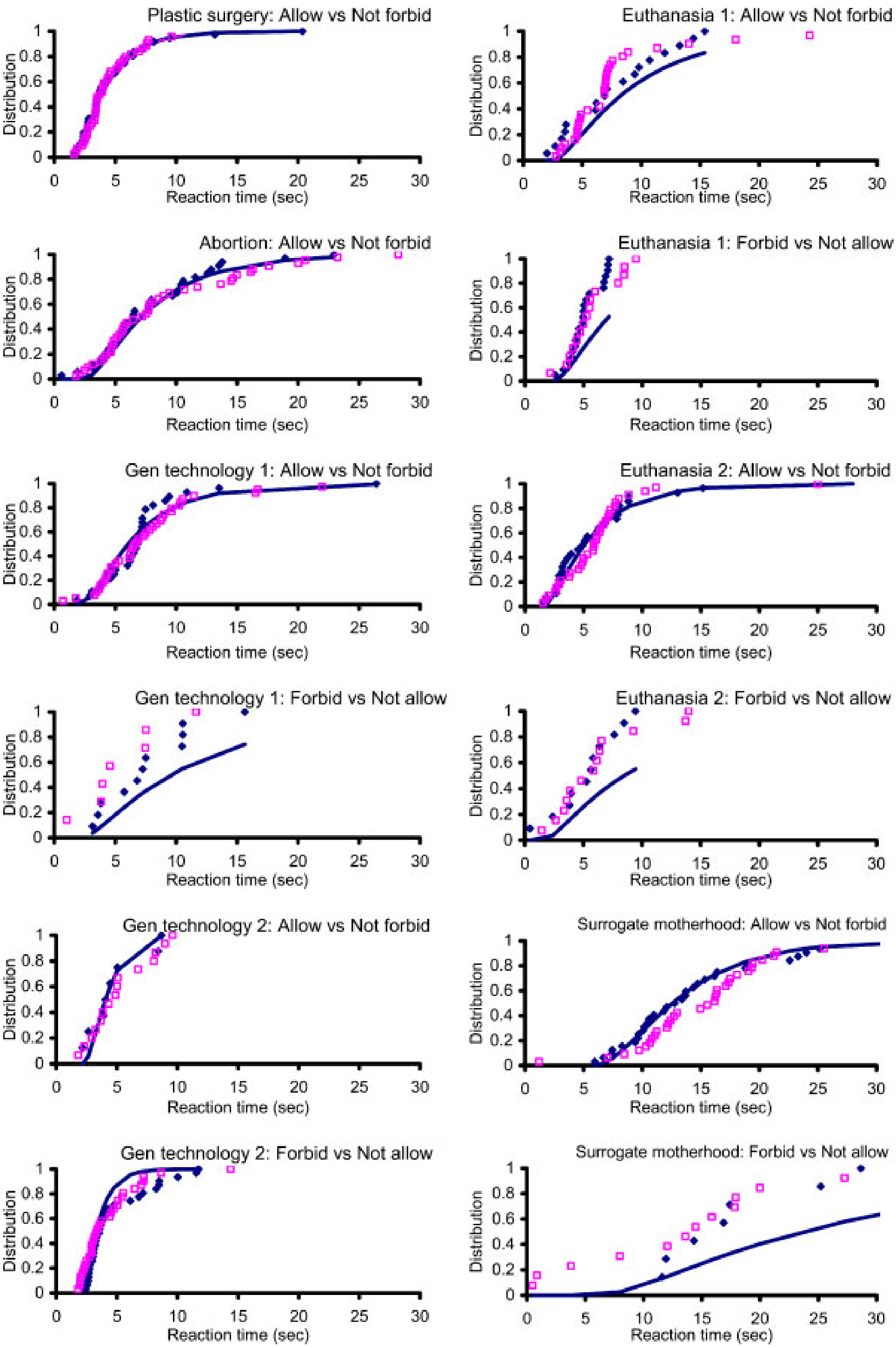

Figure 3. Acquisition time distribution functions (thick curves) fitted to the empirical distributions of

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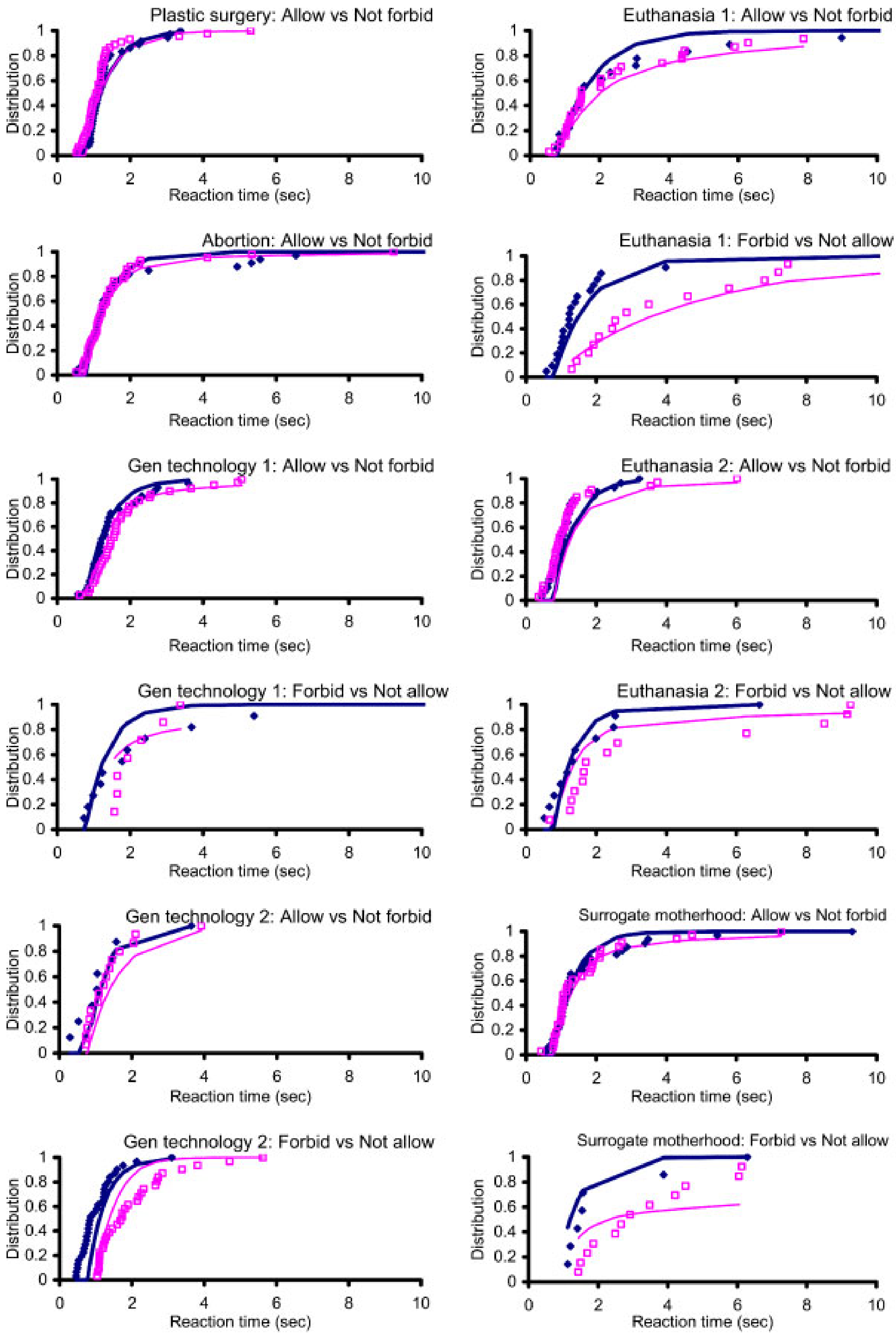

Figure 4. Answering time distribution functions (thick curves) fitted to the empirical distributions of 'yes allow' and 'not allow' (black dots), and the predicted distribution functions for the forbid questions (thin curves; open squares are data), with memory search probability p varying across questions

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Table 5. Test results for the fitted acquisition and answering time distributions for 'yes forbid' (YF) and 'not forbid' (NF), and the response probabilities of 'yes forbid', for different memory search probabilities p, over the seven forbid questions

		Number of rejections					
Model version	Test size	AcqYF	AcqNF	AnswYF	AnswNF	Prob. YF	Total
$p=0$	$\alpha=0.025$	0	1	3	2	1	7
	$\alpha=0.05$	2	1	3	5	3	14
$p=0.2$	$\alpha=0.025$	0	1	2	0	2	5
	$\alpha=0.05$	2	1	3	2	2	10
$p=0.4$	$\alpha=0.025$	0	1	2	1	1	5
	$\alpha=0.05$	2	1	2	1	2	8
$p=0.6$	$\alpha=0.025$	0	0	0	1	1	2
	$\alpha=0.05$	2	1	2	1	1	7
$p=0.8$	$\alpha=0.025$	0	0	0	1	2	3
	$\alpha=0.05$	2	1	1	1	2	7
$p=1$	$\alpha=0.025$	0	0	3	1	4	8
	$\alpha=0.05$	2	1	3	2	4	12
p varies across questions	$\alpha=0.025$	0	0	0	0	1	1
	$\alpha=0.05$	2	1	0	1	1	5

For every value of p, we tested the 24 distribution functions with Kolmogorov's test. [7] The test results are shown in Table 5. The model performs worst for $p=0$, which gives the most rejections. The model does not fit much better for $p=1$, which is the model version with the largest forbid/allow asymmetry. This can be explained in part by the statistical findings in the Section on Data, which tell us that not all the questions show a forbid/allow asymmetry. Considerable improvements are obtained by setting p at 0.6, which reduces the number of rejected distribution functions and response probabilities by more than 50%.

Fixing the value of p across questions means that the chance of an additional memory search after the first feature retrieved is merely respondent-specific and is not affected by question. However, the data analyses in the Section on Data showed a statistically significant forbid/allow asymmetry for only two questions. Variation of p over questions leads to no rejection of all the acquisition time and answering time distributions at alpha = 0.025. Only the response probability of a 'yes forbid' answer to the question on surrogate motherhood does not fit the data. The test results for varying p across questions are also shown in Table 5. The memory search probabilities that were used for the question on plastic surgery, the two questions on euthanasia, the question on abortion, the two gen-technology questions, and the question on surrogate motherhood are: $p=0.2$, 0.8, 0.4, 0.5, 0.5, 1, and 0.8, respectively. The corresponding predicted acquisition time and answering time distribution functions are shown in Figures 3 and 4, respectively. The response probabilities for 'yes forbid' that correspond with these fits are given in Table 6.

The response probabilities of 'yes forbid' cannot be fitted without rejections. The response per cent of 'yes forbid' for the surrogate motherhood question shows a picture that

[7]We chose Kolmogorov's statistic for two reasons: (1) we will test simple null-hypotheses, that is, the distribution functions for the forbid questions are fully specified by the parameter estimates based on the allow data; (2) the distribution functions apply to continuous random variables (i.e. reaction times). The Kolmogorov test does not take into account degrees of freedom, so that we did not use it for the fits on allow data. The seven response probabilities of 'yes forbid' were tested on the basis of binomial distributions.

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Table 6. Response probabilities for 'yes forbid' for each of the seven questions, given the probabilities for 'not allow' that correspond with the fits of Figures 3 and 4, with memory search probability p varying across questions

	Not allow (%)		Yes forbid (%)	
Question	Data	Model	Data	Model
Plastic surgery	7.7	7.7	4.3	6.3
Euthanasia 1	53.8	58.5	32.6	39.1
Euthanasia 2	28.2	30.1	28.3	21.7
Abortion	15.4	15.4	8.7	8.9
Gen-technology 1	28.2	30.4	15.2	19.8
Gen-technology 2	79.5	79.7	67.4	63.6
Surrogate motherhood	17.9	18.9	28.3	6.2

The observed data are also given.

is opposite to the other questions, as the response scores for 'yes forbid' are greater than those for 'not allow'. It is not clear why the reverse effect in the response scores occurs.

DISCUSSION

In this study, we presented a model for the response process for forbid/allow attitude questions. The underlying mathematical model is based on point process theory, which is the basis of the neurobiologically inspired Memory Chain Model. This MCM model was extended and refined to allow an application to the context of answering attitude questions. In the new model, we still consider a 'point' as a feature of a memory representation (e.g. of a topic asked about), to which we associate here a binary-valued evaluation (i.e. an attitude). Together with the response mapping process illustrated in Figure 2, this marked point process enables us to derive mathematical expressions for the reaction time distributions and response probabilities of the answering options.

In this section, we will first review several model assumptions and parameters that are essential to explaining the forbid/allow asymmetry, which was the objective of this study. Next, we discuss the results obtained in the previous section. Finally, we suggest topics for future research and conclude with some remarks on the value of the results of this study to survey research and cognitive science.

We developed a model to describe the processes of response underlying the asymmetry in the number of 'not forbid' and 'yes allow' answers. The only model parameter that can be varied in order to explain the asymmetry in forbid/allow answers is the difference, between forbid and allow questions, in the amount of retrieved information to select an answer. It would be illogical to attribute the forbid/allow asymmetry to differences in the intensities of features with positive and negative evaluations between the two versions of a question. One word is substituted, but the topic asked about and the objective of the question remain the same. In addition, changes in the intensity of either positive or negative evaluations would give rise to asymmetry effects during both the acquisition and the answering phase. This, however, does neither emerge from the data, nor from previous experiments (Holleman, 1999a).

Hence, in the model proposed here, the only factor that was allowed to differ in the response process to forbid/allow questions is the amount of information retrieved during

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the answering stage. This mathematical model was demonstrated to give an adequate description of the empirical data obtained. Although we used the simple assumption of exponentially distributed comprehension and judgment times, the reaction time distributions and response probabilities fitted the data for the allow questions. This model was able to predict the acquisition time and answering time distributions of six out of seven forbid questions. The results show that the response process model is able to offer an explanation for the forbid/allow asymmetry.

The results of the current study are in line with the outcomes of previous, correlational, research. This supports the idea that the separate measurement of acquisition times and answering times is useful and fruitful. The wording effect does not arise during the acquisition stage of the response process: some sort of core issue is distilled from the question text and information about this attitude object is being retrieved. During the answering stage a difference arises; something happens that causes the attitudes measured with forbid/allow questions to be mapped differently on the yes/no scales of the two question versions. Two questions can be raised with regard to what happens exactly during this answering stage, and also about whether it can actually be as clearly delineated from the acquisition stage as suggested throughout this paper.

The first question is what happens during the answering stage causing it to take more time for 'yes forbid'-answers. It could be assumed that translating an attitude into a 'yes' to forbid questions is just more difficult, as to forbid is more extreme than the other response options. If one has to make a more difficult mapping decision, this will take longer than an easier decision.

In this paper, the model assumption is that the extra time spent on this mapping task is due to an extra memory search. It is plausible that for a respondent to take an extreme position (especially to say 'yes' to a forbid question), he would like to retrieve extra arguments to be sure about his stance, or to be able to defend it to an outsider. It is important to note that this does not mean that a new or different attitude is being retrieved. It merely indicates that, before a respondent can decide to map his attitude onto 'yes forbid', an extra (negative) attribute of the same attitude or attitudinal network is being activated. It will be very difficult to empirically demonstrate whether this actually takes place. Thought-listing experiments may give some insight when it would turn out that the number of arguments listed by (yes) forbid respondents is systematically larger.

A second question is how clearly the answering stage can be demarcated from the acquisition stage. This question can be answered empirically, through the design of additional experiments, as well as mathematically, by making the consequences of various assumptions visible.

Empirically, it is not at all sure whether the reaction times called answering times in this research measure only a process of answering. Respondents may press a key at the end of the acquisition phase in order to view the response options while still gathering information to form an opinion. During the answering phase they may go back to the acquisition stage when it turns out to be difficult to select an answer and therefore collect more information. So, acquisition may continue after a key has been pressed to start the answering time measurement. Also, it is uncertain whether the answering stage really only starts when the response options appear on screen, or whether it starts earlier, as the question wording itself already gives a hint about what type of answer will be expected: after the phrase 'Do you think...' a 'yes' or 'no'-answering scale can be anticipated.

Additional experiments could be set up in which the acquisition times and answering times measured separately according to the procedure used in the present study are

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compared to latencies obtained while the answering options are available immediately. Also, within the acquisition times, the reading times and the attitude retrieval and formation times can be distinguished by providing subjects with a very short story and a sentence verification task (e.g. with the sentence 'The government should forbid abortion') and compare the reading time with the acquisition time for an equivalent survey question ('The government should forbid abortion. Agree–Disagree').

Mathematically, it is interesting in this respect to consider the assignment of the four stages of the response process in Figure 1 to the acquisition phase and the answering phase. In the Section on Model Characteristics, we assumed that the acquisition phase consists of Stages (1) and (2) of the response process depicted in Figure 1, while Stages (3) and (4) take place during the answering phase. This framework enables us to formulate and investigate an alternative: the acquisition stage only consists of Stage (1), that is, the question is merely read and memory search starts only when the answering categories are shown. In this alternative, the acquisition time distributions are identical for the four answering possibilities. However, the acquisition time distributions for the answers 'yes allow' and 'not allow' concerning the first question on euthanasia are different (Kolmogorov–Smirnov two-sample test, alpha = 0.05). Other questions also show large differences, such as for the acquisition time distributions of 'yes allow' and 'not allow' of the surrogate motherhood question, but the small sample sizes do not result in significant statistical differences. These results justify the phasing in the acquisition and answering stage as is done in our model.

We believe that the results of this study are valuable for increasing the understanding among survey researchers about the cognitive and decision processes underlying answering behaviour in respondents. The differences in the response processes for allow and forbid questions give more insight into the main variable, the attitude or opinion that a questionnaire intends to measure. On the other hand, this study also shows the benefits of survey research for cognitive theories. The specific set-up of the survey experiment and the data analyses have led to refinements of the Memory Chain Model with regard to memorised information (attitudes) and, most of all, response (mapping) processes, in a direction that did not emerge in previous memory retention studies.

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APPENDIX A
FORBID/ALLOW QUESTIONS USED IN THE EXPERIMENT

1. Do you think the government should allow (forbid) cosmetic plastic surgery? Yes/No;
2. Do you think the government should allow (forbid) euthanasia on people who are not sufficiently lucid anymore to decide for themselves? Yes/No;
3. Do you think the government should allow (forbid) euthanasia if someone suffers mentally? Yes/No;
4. Do you think that the government should allow (forbid) abortion of a child with a genetic disorder? Yes/No;
5. Do you think the government should allow (forbid) screening for genetic disorders in unborn children? Yes/No;
6. Do you think the government should allow (forbid) parents to choose the baby's sex? Yes/No;
7. Surrogate motherhood is allowed if the 'wish parents' are in direct touch with a surrogate mother and if it is medically impossible for them to become pregnant themselves because the uterus was removed. So for couples that cannot become pregnant for other reasons, this law does not provide a solution. Do you think the government should allow (forbid) 'wish parents' for whom the cause of infertility cannot be established to turn to a surrogate mother? Yes/No.

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