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Resource report

Mixing modes and measurement methods in longitudinal studies

Annette Jäckle, Alessandra Gaia, Michaela Benzeval

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CLOSER
UCL Institute of Education
20 Bedford Way
London
WC1H 0AL
United Kingdom

Tel: +44 (0)20 7331 5102
Email: closer@ucl.ac.uk
Web: www.closer.ac.uk
Twitter: @CLOSER_UK

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Introduction

Across the world longitudinal studies are facing falling response rates, at the same time cost imperatives are bringing into question the feasibility of large scale regular face-to-face data collection. While, the rapid development of communications technology and associated cultural changes is assumed to mean that study participants will increasingly expect to be able to answer surveys when and how it suits them. All of these factors are driving longitudinal studies to combine different modes of data collection both to increase response and to reduce costs. Mixing modes of data collection either across individuals at one point in time or within individuals over time, presents longitudinal researchers with a range of methodological challenges in both data collection and analysis. Within CLOSER, and beyond, studies are investigating different aspects of the implications of mixed mode data collection, and giving data users varying degrees of support and advice about issues that should be of concern.

Drawing on evidence from across CLOSER's longitudinal studies, this report reviews the latest evidence gathered on the effect of mixing modes and measurement methods on response, measurement issues and survey costs. The review also focuses on the implications for analysis of measures collected in different ways either across individuals at the same point in time or within individuals over time. Building on these reviews, we identify what further research is required in relation to both the design and analysis of mixed mode data collection.

The contents of this report is based on a CLOSER workshop held in November 2016 (http://www.closer.ac.uk/event/mixing-modes-measurement-methods-longitudinal-studies/).

The workshop and report were funded by a CLOSER Innovation grant awarded to Michaela Benzeval and Annette Jäckle (University of Essex), and Kate Tilling and Dr Andy Skinner (University of Bristol) and are part of a series of three reports (see Jäckle, Gaia, & Benzeval, 2017; Stone & Skinner, 2017).

Background

The main distinctions between different modes of data collection are in the extent of interviewer involvement, and the degree of computerisation (Groves et al., 2011). Most CLOSER studies started with face-to-face interviews. In some cases the questionnaire is programmed on a laptop (Computer Assisted Personal Interview, CAPI), in some cases the questionnaire is printed on paper (Paper and Pencil Interview, PAPI). Similarly most telephone interviews are computerized (Computer Assisted Telephone Interview). Self-completion modes are also used by the CLOSER studies. These can be either printed on paper, programmed on the interviewer's laptop but handed over to the respondent to complete on their own (Computer Assisted Self-Interview), or implemented as a web survey.

Different modes can be combined to achieve different goals (De Leeuw, 2005): to increase response rates (by following up on non-respondents in a different mode), to save costs (by starting with a cheaper mode), or to improve measurement quality (by using self-completion questionnaires for sensitive questions).

A first scenario is where interviewer and self-completion modes are used in combination (e.g. in *Understanding Society* or the Millennium Cohort Study). The self-completion questionnaires are used for sensitive questions, where it is thought that respondents will give more truthful answers if they report anonymously rather than to an interviewer. In this case, all respondents answer a given question in the same mode; the mode differs between questions but not between respondents, within wave or over time.

A second scenario is where different respondents answer the same question in different modes. Sample members might be given a choice of modes ("concurrent mixed modes"), or they might first be invited to complete the interview in a cheaper mode such as web, and then followed up in another mode (such as telephone or face-to-face) if they do not complete the web survey ("sequential mixed modes"). Alternatively, different sample members might be allocated to different modes upfront. The allocation might be random for the purposes of an experiment, or might be based on known characteristics of the sample members.

A third scenario in longitudinal studies where the mode is changed for the same question over time. For example, a number of CLOSER studies have alternated between telephone or web and face-to-face interviews over time.

Longitudinal studies have particular scope to maximize the benefits of mixed mode surveys (Lynn, 2013): first, sampling frames often do not include contact information that would be needed to implement cheaper modes. In a longitudinal survey respondents can be asked for their contact details (including telephone numbers and email addresses), such that cheaper modes can be used in subsequent waves. Second, the survey can be used to collect data about sample members that allow targeted allocations to modes (Kaminska & Lynn, in press), for example by asking about the respondent's mode preferences. In a targeted design, sample members who are likely to complete the interview online might, for example, be sent an invitation to complete the survey by web, whereas all other sample members might be contacted by an interviewer. Third, in a longitudinal setting, sample members are already familiar with the survey content and have already experienced one or more interviews. Thus, it might be easier to convince a sample member to participate in a self-administered mode of data collection, as there might be less need to rely on the interviewers' persuasion skills than in a cross-sectional setting.

This report focuses on the second and third scenario above: where different respondents answer the same question in different modes at the same time or over time. They key question is whether answers given in different modes are comparable. We base our examination of comparability on the Total Survey Error framework (Groves et al., 2011). The key idea of this framework is that the quality of a survey estimate (e.g. how well the estimated mean matches the true mean of the population of interest) can be affected by errors occurring at different stages of the survey data collection. These errors can affect either representation (how well the respondent sample matches the population of interest), or measurement (how well the values in the data match the theoretical concepts of interest). In addition, errors can lead to either biases (e.g. systematic deviations from the true mean) or increased variance. On the measurement side, errors can occur due to misspecification (e.g. the survey question does not match the intended theoretical concept), due to measurement error (either due to errors by the respondent, errors or unintended influences of the interviewer on the respondent's answer, or errors or unintended influence of the questionnaire), or due to processing error (e.g. coding). On the representation side errors can occur due to mismatches between the units included in the sampling frame and the population of interest (coverage error), due to sampling, non-response, or errors made in statistical adjustments (e.g. weighting, imputation). Data collected with different modes are comparable if the errors affecting measurement and representation are similar. In this review of the use of mixed modes in CLOSER studies, we focus on what is known about differences in measurement errors, non-response errors, and adjustment errors between modes.

Use of mixed modes in UK longitudinal studies

Table 1 summarizes the use of mixed modes in the UK CLOSER studies. Some studies have adopted a mixed-mode design: *Understanding Society*: the UK Household Longitudinal Study (UKHLS), the National Child Development Study (NCDS), the Avon Longitudinal Study of Parents and Children (ALSPAC), and the Millennium Cohort Study (MCS). Other studies, such as the British Cohort Study 1970 (BCS70) and the Southampton Women's Survey (SWS), have collected most of the questionnaire data using the same mode for all respondents, but have adopted mixed-mode designs for the some sections of the questionnaires (e.g. the self completion sections). The MRC National Survey of Health and Development (NSHD) and the Hertfordshire Cohort Study (HCS) have to date not used combinations of modes in a single wave.

Understanding Society: the UK Household Longitudinal Study has been experimenting with mixed modes since 2009, using its Innovation Panel. The Innovation Panel is a separate survey that mirrors the design of the main *Understanding Society* survey and is used to test methodological innovations in longitudinal studies, in general, and *Understanding Society,* in particular. The Innovation Panel wave 2 experimentally tested a sequential mixed mode design with telephone followed by face-to-face interviews, compared to face-to-face only (Lynn, 2013). Since wave 5 a random 2/3 of households have been allocated to a sequential web then face-to-face design (including a final telephone stage in later waves), with the control group being assigned to face-to-face (with web and telephone follow-ups of non-respondents in later waves) (Jäckle, Gaia, Baghal, Burton, & Lynn, 2017). Based on the results of the Innovation Panel, a sequential design including web followed by face-to-face and then telephone has been implemented in the main *Understanding Society* survey: in wave 7 households who did not participate in the previous wave were allocated to mixed modes. From wave 8 onwards all but 20% (a ringfenced face-to-face) sample of households have been allocated to mixed modes using a targeted approach to select those who are web first (Carpenter & Burton, 2017).

The National Child Development Study (NCDS) Age 55 survey adopted a sequential mixed-mode design, with respondents being invited to participate to the study by web, and non-respondents being followed-up by telephone. This was the first use of a mixed-mode approach in the history of the study; all previous NCDS sweeps were administered by face-to-face interviewing with the exception of the Age 46 survey, where telephone interviewing was adopted (Brown, 2016a).

Next Steps (previously known as the Longitudinal Study of Young People in England, LSYPE, and while not formerly a CLOSER study is strongly linked to the consortium) adopted face-to-face interviewing for the first four waves. For waves 5, 6, and 7 a mixed-mode approach was adopted, with web followed by telephone, followed by face-to-face interviews. At wave 8 (age 25), a similar sequential mixed mode design was implemented (with web, followed by telephone, and face-to-face interviews); however, the telephone option was available only for wave 7 respondents.

The British Cohort Study 1970 (BCS70) has adopted multiple modes of data collection within and between waves, but the same questions have never been asked in different modes within a wave. The Age 34 and Age 42 surveys included both paper self-completion questionnaires and CASI for different questionnaire modules. In other survey waves, the self-completion section was administered only with paper self-completion questionnaires (from birth to age 16) or only with CASI (at age 30). The main questionnaire was administered with different modes in different waves, but, within waves, all respondents participated in the same mode. Data were collected with pen-and-paper interviewing PAPI (from birth to age 16), mail surveys (Age 26), Computer-Assisted Personal Interview CAPI (Age 30, 34, and 42), and Computer-Assisted Telephone Interview CATI (Age 38).

The Millennium Cohort Study (MCS) has adopted face-to-face interviewing (CAPI), but the self-completion sections have been administered in different modes across waves, with the adoption of Computer Assisted Self-Interviewing CASI (Age 9 months), a mix CASI and paper self-completion questionnaires (Age 3), a mix of CASI and mail survey (Age 14), and a mix of CASI, paper self-completion questionnaires, and mail survey (Age 5, 7, and 11). In the Age 14 survey, an online survey, a smartphone app and a paper version for the time use diary were implemented (Chatzitheochari et al., 2015).

Similarly, data for the Avon Longitudinal Study of Parents and Children (ALSPAC) have been collected for the most part using the same mode of data collection for all respondents in the main data collection. In addition, in its separately administered questionnaire data collection, more recent waves have included a mix of different modes. Specifically, data in ALSPAC have been collected through face-to-face interviews and clinical assessments. In addition, self-completion questionnaires were administered separately using a mix of paper self-completion and mail surveys, until age 18, and sequential mixed-mode paper and web self-completion from age 18 onwards.

Data from the Southampton Women's Survey (SWS) have been collected using face-to-face interviews, medical assessments, cognitive measurements (assessed with computers), and self-completion paper diaries. While the survey has not used mixed-mode data collection for the whole questionnaire, modes have been mixed for specific scales – for example self-report administrated questions have been used in conjunction with clinical assessments for measuring pubertal stage.

The MRC National Survey of Health and Development (NSHD) has adopted multiple modes of data collection, including face-to-face interviews, mail questionnaires and medical assessments over time, but never adopted mixed-mode data collection within a wave.

Similarly, the Hertfordshire Cohort Study (HCS) which is based on retrospective identification of the sample from child health ledgers in the 1920s and 1930s, followed up with face-to-face interviewing in the 1980s, which includes a medical assessment: after the interview, participants are invited to attend a local clinic for the collection of additional health data. A follow-up study was conducted 7 years after the first round of interviews, using a mail questionnaire.

Table 1: The use of Mixed Modes in CLOSER and associated Studies

CLOSER Study name	Use of Mixed Modes	Modes adopted
Avon Longitudinal Study of Parents and Children (ALSPAC)	Self-completion module	From age 18: mixed-mode (annual paper and web self-completion surveys)
Millennium Cohort Study (MCS)	Self-completion module, Time use diary	Mixed mode: Age 3: CASI and paper, Age 5, 7, 11: CASI, paper, and mail, Age 14: CASI and mail; Time use diary: app study, web, and paper.
Next Steps	Main survey	Waves 5, 6, and 7: sequential mixed-mode design, with web followed by telephone, followed by face-to-face. Wave 8: sequential mixed-mode design, with web interviews, followed by telephone and face to face interviews, (telephone option available only to wave 7 respondents)
National Child Development Study (NCDS)	Main survey	Age 55 survey: sequential mixed mode design with web, followed by telephone
Southampton Women's Survey (SWS)	Only for specific items	Mix of self-reports and clinical assessments
Understanding Society: the UK Household Longitudinal Study	Main survey	Mainstage waves 3 to 6: telephone interviews in a mop-up phase at the end of the face-to-face fieldwork for non-respondents Mainstage 7 and 8: some sample members allocated to a sequential mixed-mode design (web followed by face-to-face),

		with telephone follow-up at the very end of the fieldwork; others allocated to a face-to-face only design. Innocation Panel 2 (IP2): randomised allocation to face-to-face or sequential mixed-mode design, with telephone followed by face-to-face IP5: randomised allocation to face-to-face or sequential mixed-mode design, with web followed by face-to-face. IP6-IP11: randomised allocation to face-to-face first sequential mixed-mode design, with web followed by face-to-face (with telephone and web follow-up at the very end of fieldwork).

Effects of mixed modes on unit non-response/attrition

Mixed-mode designs have mainly been introduced as a possible way of reducing survey costs. At the same time, it is thought that mixed mode designs might reduce non-response bias, if respondents have different propensities to participate in a survey, depending on the mode: subgroups that are underrepresented in a single mode survey might be better represented in a mixed-mode survey (De Leeuw, 2005; Jäckle, Lynn, & Burton, 2015; Lynn, 2013). These ideas have been put into practice in sequential designs, where cheaper modes are usually used first, followed by more expensive ones to interview hard-to-reach respondents or households (De Leeuw, 2005).

While the methodological literature on the effect of mixed mode surveys on non-response and attrition is expanding, it is still limited. This is largely due to the fact that the majority of experimental studies examining the effects of mixed mode data collection are conducted in a cross-sectional setting (e.g. Fong & Williams, 2011; Janssen, 2006; Lagerstrøm, 2008; Leesti, 2010; Link & Mokdad, 2006; Martin & Lynn, 2011; Millar & Dillman, 2011; Olson, Smyth, & Wood, 2012; Smyth, Dillman, Christian, & O'Neill, 2010). While several longitudinal studies have begun to implement mixed mode data collection, only few have done so experimentally allowing examination of the effects of mixed modes on measurement and representation. Among the CLOSER studies, the effect of mixed-mode on unit-nonresponse and/or attrition has been analysed in *Understanding Society*: the UK Household Longitudinal Study, in the National Child Development Study, and in Next Steps.

In the *Understanding Society Innovation Panel* the first experiment at wave 2 compared a sequential design where interviews were first attempted by telephone, and non-respondents were followed up by face-to-face interviewers (Lynn, 2013). The experiment was designed to identify the best criteria for moving sample members to the next mode: in the “telephone intensive” protocol telephone interviews were attempted with each household member, and they were only moved to face-to-face if no interview was achieved by telephone. In the “telephone-light” protocol all household members were moved to face-to-face as soon as one person in the household required a visit by an interviewer. In wave 2 (when this experiment was implemented), both individual and household response rates were lower in the two mixed-mode design than in the single mode design. The two different mixed mode protocols did however not produce different response rates. The experiment had lasting effects in the following waves, although all sample members were then interviewed face-to-face: the household response rate for the “telephone light” group was significantly lower than for the “telephone intensive” or the face-to-face only group (Lynn, 2013). Although the mixed mode design affected response rates, there were only minimal differences in non-response biases between the three experimental groups.

In subsequent waves of the *Understanding Society Innovation Panel*, experiments were implemented to study the effect of introducing a sequential mixed-mode design, with web followed by face-to-face interviews, compared to face-to-face only. At wave 5 (the first wave in which this experiment was fielded), the mixed-mode design led to lower household completion rates than the unimode face-to-face design. Across all respondent characteristics tested, sample members assigned to mixed modes had a lower propensity to participate than sample members assigned to the face-to-face design: there was no socio-demographic group with a higher propensity to participate if allocated to the mixed-mode design (Jäckle et al., 2015). At the following wave (wave 6), when this experiment was repeated maintaining the same treatment allocations, there is no difference in attrition rates between the mixed mode group and the face-to-face group (Bianchi, Biffignandi, & Lynn, 2017). Similarly, preliminary analysis of experimental data from the main *Understanding Society* survey (wave 8) suggests that the introduction of sequential web-face-to-face design does not increase attrition compared to a unimode face-to-face design (Carpenter & Burton, 2017). In both the Innovation Panel and the main Understanding Society experiments, some sample members allocated to mixed mode were however offered higher incentives than sample members allocated to face-to-face. Further research using Innovation Panel data has shown that the mixed mode design leads to lower response rates if all sample members are offered the same incentive. Only when those allocated to mixed modes are offered higher incentives (either a higher unconditional incentive or adding a bonus conditional on completing the survey online) does the mixed mode design produce similar response rates to the face-to-face design (Gaia, 2017).

The National Child Development Study Age 55 survey and the Next Steps age 25 surveys have also investigated the effect of mixed-mode on unit non response. The aim of these studies is to interview the cohort member (rather than the entire household), thus, the evidence that these experiments provide is at the individual level, instead of the household level.

The National Child Development Study (NCDS) Age 55 Survey adopted an experimental design to test the effect of mixed-modes on non response and measurement error: 1/7 of sample members were allocated to a unimode telephone design, while the remainder 6/7 were allocated to a sequential mixed mode design, with web followed by telephone interviews (Goodman, 2016). The mixed mode design achieved a higher response rate (82%) than the telephone only design (77%). Only “frequent computer users” were significantly more likely to participate in the study if allocated to the mixed-mode design *versus* the telephone only design, though the difference was small. Thus, the resulting sample composition, in terms of observable characteristics and previous wave participation, was similar across the two groups, suggesting that the mixed mode design does not have much effect in reducing (nor increasing) response bias (Goodman, 2016).

The Next Steps age 25 survey also adopted a mixed mode design, though not experimentally: sample members were invited to complete the survey online, and non-respondents were followed up with telephone and face-to-face interviews. The telephone option was used only for web non-respondents who had given an interview in the previous wave. The mixed mode design lead to a 50% response rate. Overall, most respondents (61%) participated in the survey by web, 9% participated by telephone, and 30% were interviewed face-to-face (Calderwood, 2016b). Although the study did not include an experimental comparison, the web component of the mixed-mode survey was considered particularly successful, and seems to have helped to address the challenge of locating sample members in a study of an age group with high residential mobility and with long gaps (of at least 5 years) since the last contact with sample members (Calderwood, 2016b). Preliminary results suggest that the subsequent modes may not have significantly improved representativeness (Calderwood, 2016b).

To sum up, the evidence from CLOSER studies on the effect of introducing a mixed-mode design in an otherwise unimode longitudinal UK survey is mixed. Some have found that using mixed modes reduces attrition, others that it increases attrition compared to unimode designs. Most have found no support for the expectation that mixed modes reduce non-response bias, by bringing in respondents who would not participate in the original unimode design. The CLOSER studies compared are however very heterogeneous. They have examined different mode combinations: telephone and face-to-face (Lynn, 2013); web and telephone (Goodman, 2016); web, telephone, and face-to-face (Calderwood, 2016b); and web and face-to-face (Bianchi et al., 2017; Carpenter & Burton, 2017; Gaia, 2017; Jäckle et al., 2015). The studies also vary by target population: age 25 (Calderwood, 2016b), age 55 (Goodman, 2016), and the general population (Bianchi et al., 2017; Carpenter & Burton, 2017; Gaia, 2017; Jäckle et al., 2015). Replication studies are therefore needed to derive more robust conclusions on the effect of the different mixes of modes on response rates and biases in longitudinal studies.

The key questions on the effect of mixed modes on unit-nonresponse and attrition, which are still unresolved, are:

- What are the effects of different mixed-mode designs on non-response and attrition rates? For example with sequential versus concurrent mixed modes, with combinations of different modes, if the order of modes is varied, or if the rules for moving respondents to the next mode are changed?

- Are the effects different at the individual *versus* household level?

- What are the effects of different mixed mode designs on non-response bias?

- Can tailored approaches (e.g. assigning respondents to their preferred survey mode) be used to maximise response rates, to minimise non-response bias, and to minimize costs?

Methods to boost web response

One of the key motivations for introducing online data collection in longitudinal studies is the promise of saving fieldwork costs: as the variable cost of a web interview is much lower than the variable cost of a telephone or face-to-face interview, the expectation is that pushing respondents to complete the survey online will reduce costs. The cost reductions however depend on i) any variable costs of the method used to increase web response, ii) effects of this method on fixed costs of data collection, and iii) the proportion of the sample who do not require interviewer administration of the survey. In surveys where multiple household members are interviewed, savings only accrue if all complete their survey online such that no interviewer has to contact the household.

Different methods have been trialled to increase the proportion of a sample who complete the survey by web, including offering incentives conditional on completing the survey online, increasing the length of the web fieldwork period, sending invitation letters by email instead of mail, and targeted allocation of sample members to web, based on respondent mode preferences or predicted propensities to respond by web.

Offering incentives conditional on web response within a certain time period can be effective in increasing web response and reducing fieldwork costs. In the Next Steps Age 25 survey the use of incentives to boost web response was implemented experimentally (Calderwood, 2016b). A random group of respondents was offered a £20 incentive if they completed the survey online within the first three weeks of web fieldwork, and £10 if they completed the survey online after the cut-off date. The control group were offered a £10 incentive conditional on completing the survey, regardless of the mode. (Calderwood, 2016b). As expected, web response rates were higher among respondents offered the conditional web incentive compared to the control group (25% *vs*. 20%, N=1116; 1120); using higher incentives generated an estimated cost saving of approximately £25.000-£30.000, which results from the lower number of cases issued to face-to-face interviews (Calderwood, 2016b).

A similar approach was implemented as part of an adaptive design approach at Wave 8 of *Understanding Society*. In one randomised group each adult sample member was offered an additional £10 incentive if all eligible adults in their household completed the survey online within the first 2 weeks of fieldwork. In the other group the bonus was offered conditional on the individual completing the survey online within the same time period (Carpenter & Burton, 2017). The proportion of households where all eligible adults completed their survey online was not significantly different in the two groups.

Varying the time limit for the web completion bonus (20 days *vs*. 34 days) had no significant effect on full household web response (Carpenter & Burton, 2017). Increasing the length of the web only fieldwork period before issuing cases to face-to-face interviewers also had no statistically significant effect, although: increasing the length of web fieldwork from three to five weeks, along with increasing the number of reminders (but maintaining the cut-off for the web completion bonus at 20 days), led to higher full household web response. The increased costs of reminder mailings were more than off-set by the reduction in face-to-face interviewing costs.

The mode in which the invitation to the web survey is delivered might also affect web take-up. Sending the invitation by email rather than by post is likely to boost web response in several ways: including a link to the survey that respondents can click reduces respondent burden and the risk of errors in copying and typing the URL from a letter (Millar & Dillman, 2011). If respondents receive the invitation while already online, they might be more likely to participate in the survey by web. More generally, email communication might increase survey response by increasing the likelihood of successfully contacting sample members (Cernat & Lynn, 2017, in press), although there is evidence that not all emails reach sample members: in wave 6 of the *Understanding Society* Innovation Panel only 30% of email invitations were opened (Wood & Kunz, 2014). Nonetheless, experimental data from the *Understanding Society* Innovation Panel provide evidence of expected positive effects: sending invitations to a web survey by email, in addition to mail, increases the proportion of respondents who complete the survey online, although it does not increase the overall response in a sequential web-face-to-face survey, compared to face-to-face only (Cernat & Lynn, 2017, in press).

Targeting strategies might also increase web take up, by inviting only respondents to the web version who have a preference for being surveyed online or who have a higher predicted probability of participating online. In longitudinal studies, respondents can be asked what their preferred mode is, and can then be approached with their preferred mode in subsequent waves. Mode preferences have been found to be predictive of the mode of response in a subsequent survey wave (Kaminska & Lynn, 2013). There are however drawbacks in using a tailored approach based on mode preference: evidence from the *Understanding Society* Innovation Panel has shown that for most respondents mode preferences are not stable attitudes and answers to questions on mode preferences are influenced by contextual factors (Al Baghal & Kelley, 2016).

Targeting can alternatively be based on the predicted probability of a sample member responding by web being higher than that of other sample members, or being higher than the probability of responding in other modes. Simulation studies from the *Understanding Society* Innovation Panel suggested that the first approach is effective (Kaminska & Lynn, in press) Allocating only sample members with a higher propensity to respond by web to a sequential web and face-to-face design led to a higher web response than issuing the same proportion of respondents to the same design without targeting. This approach was adopted in the main *Understanding Society* survey from wave 8 onwards.

Further questions regarding methods of boosting response to web in mixed mode surveys include:

- Which methods of increasing web response are cost effective?
- What are the effects on fixed versus variable costs of different methods of increasing web response?
- How do different targeting strategies compare?

Effects of mixed modes on item non-response

Previous evidence shows that the level of item non response varies by survey mode and is typically higher in self-administered than in interviewer administered modes: for example it is higher in mail surveys than in web (Lesser, Newton, & Yang, 2012), higher in web than in face-to-face (Duffy, Smith, Terhanian, & Bremer, 2005; Heerwegh, 2009; Jäckle et al., 2015), and higher in both web and mail than in telephone (Lesser et al., 2012). To ensure comparability of data collected with mixed modes, it is however important to reach similar (and minimum) levels of item non response in each mode.

One reasons for differences in item non-response rates between modes is related to how non-response options (don't know, refused) are communicated to the respondent. In interviewer administered surveys these options are available to the interviewer, but not read out to the respondent: the interviewer selects the corresponding code if the respondent spontaneously says "don't know" or refuses to answer. In paper self-completion modes these answer categories are either not included (in which case the reason for a missing answer cannot be known) or they are included in the list of answer categories. When the refusal and don't know options are shown, a higher proportion of respondent selects those, increasing the item non-response rate (Krosnick & Fabrigar, 1997). In web survey other options are available. The response options can be hidden and only shown when the respondent leaves a question unanswered and clicks "next" to move to the next question.

The lower item non-response rates in face-to-face and telephone surveys might also be thanks to the interviewer who can keep the respondents engaged and motivated and implement some quality control on the answers given. One way of reducing the differences between modes is therefore to replicate, as much as possible, the interviewer presence in self-administered modes: for example motivational statements or prompts to replicate the interviewer presence in web surveys have been effective (Al Baghal & Lynn, 2015; DeRouvray & Couper, 2002; Fisher et al., 2017; Smyth, Dillman, Christian, & McBride, 2009) or at least partially effective (in two out of four items tested by Oudejans & Christian, 2010) in decreasing item non-response.

Al Baghal and Lynn (2015) experimentally compared the effectiveness of different methods of reducing item non-response in a web survey, by contrasting with item non-response in face-to-face survey. Motivational statements at different stages of the interview asked respondents to please answer the question they had skipped as it was one of the key questions in the survey. The motivational statement that was triggered immediately when a respondent left a question unanswered lead to significantly lower item non response than no statement (control group) or a motivational statement placed at the end of the survey. In addition, the immediate motivational statement reduced item non-response to a level that was similar to that in the face-to-face survey. The motivational statement in the web survey however had no effect on non-response bias: point estimates were not affected by the additional responses obtained with the introduction of motivational statements. The motivational statement urging respondents to give an answer as the question is a key question in the survey can only be implemented for a small number of questions, not as blanket method for all questions.

An alternative method of reducing item non-response in longitudinal studies is to use dependent interviewing: in the Survey of Income and Programme Participation, for example, respondents who skip a question are reminded of the answer they gave in the previous interview and asked whether this is still about right (Jäckle, 2009). To our knowledge this approach has not been tested in different modes to examine whether it would produce comparable item non-response rates in self-completion and interviewer administered surveys. This method however also has drawbacks as the preparation of preload data for the follow-up questions is costly and so this could also only be used for a small number of questions in any given survey.

Given the paucity of research on the effects of mixed modes on item non-response in longitudinal studies, key questions remain:

- Which items are particularly susceptible to higher item non-response in self-completion than interviewer assisted modes?
- Which methods are most successful in reducing item non-response?
- Which methods can be implemented for all questions in a survey, rather than for a subset of questions only?

Survey Costs

The costs of mixed mode surveys can vary greatly, depend on several factors: price versus cost, fixed versus variable costs, the modes used, the size of the sample, the proportion of the sample responding in the cheaper mode, and the complexity of the questionnaire instruments. The following discussion of these cost factors is based on (Couper, 2016).

For organisations that contract out the data collection to fieldwork agencies, researchers can estimate theoretical cost savings to the survey organisation. What matters, however, is the price that the fieldwork organisation charges. As mixed mode surveys involve considerable uncertainty about outcomes, the price charged by fieldwork agencies will reflect the uncertainty and include a buffer above the cost. For organization who do their own data collection, the actual cost can in principle be measured, although the cost data are not necessarily readily available in the necessary format. As a result few organisations report cost details.

Fixed costs are independent of the sample size or the achieved number of respondents and include the costs of developing and testing questionnaire instruments, of software and database systems, data processing and training. Variable costs depend on sample size and include interviewer time and travel, the costs of printing and posting letters, leaflets or other materials to sample members, the costs of respondent incentives, and of data entry and coding.

The total costs of a mixed mode survey depend on the fixed and variable costs of the combined modes: for example web surveys involve mainly fixed costs while face-to-face and mail surveys involve mainly variable costs. Mixing modes however always increases fixed costs compared to a single mode survey, in particular for questionnaire scripting and testing and for data processing. In addition, converting a single mode survey to a mixed mode survey involves many fixed start-up costs: converting the questionnaire for use on the new modes, building or acquiring software and systems for mixed mode case management, and modifying the editing, processing and data management systems. Whether this initial investment is written off or amortized over several waves, it affects estimated cost savings. Finally, the mixed mode design can also lead to increases in some variable cost components compared to a single mode version, for example if additional mailings or incentives are used to increase web take-up, while others i.e. interviewer travel and time may be reduced.

Since mixing modes will increase fixed costs, and possibly also variable cost components, mixed mode surveys involving web are not necessarily much cheaper than single mode interviewer administered surveys, although the marginal cost of an interview online is much lower than the cost of an interviewer administered by an interviewer. There is no evidence to date of substantial cost savings by introducing mixed mode data collection. In fact there is very little empirical evidence of the costs of mixed mode surveys in general (Couper, 2016): few longitudinal surveys have fully implemented mixed-mode data collection involving web and face-to-face, and few organisations, if any, are willing or able to share information about costs.

Both Next Steps and *Understanding Society* are currently trialling an "Open Book" system as a new way of managing the cost uncertainties for a mixed mode survey jointly with the contracted fieldwork agency (Benzeval, 2016). To date, in such contractual arrangements a fixed budget is typically agreed with the fieldwork agency, sometimes with a range of productivity adjustments if the issued sample, response rate, or questionnaire length deviate from the contract. There can be refunds for poor outcomes (for example if response rates are below target), but there is no process of reinvesting such refunds (for example in methods to increase response). The risk associated with the uncertainties about costs of a mixed mode survey cannot be effectively managed and result in the fieldwork agencies building uncertainty into their costs, and study PIs holding budget back as contingency. The objectives of the Open Book system are 1) to manage the uncertainty and risks of mixed mode within a fixed budget framework, 2) to allow adapting the survey design in response to achievements in real time, to maximise response within the fixed budget, and 3) to better understand fixed and variable costs to identify synergies across fieldwork and academic organisations and improve efficiencies. The current developments for *Understanding Society* include developing a variable cost linked to outcome framework in a spreadsheet and a process agreement for governance of the system. The spreadsheet focuses on detailed information about variable costs associated with different modes (specified in the tender), linked to predicted response rates in different modes. With the help of this spreadsheet the predicted impact of changing, for example, the number of issued or achieved households in different modes, can instantly be seen and used to agree initiatives to try to improve response in real time. The budget includes a small development fund, to provide space for initiatives to improve response as 'problems' arise.

Key questions regarding the costs of mixed mode surveys are:

- How do fixed and variable costs change with mixed mode designs, compared to single mode surveys?

- Which survey design features determine fixed and variable costs?
- Which mixed mode designs can lead to reductions in data collection costs?
- What can be done to manage the risks and uncertainties of mixed mode surveys in different kinds of contractual arrangements with fieldwork providers?
- How can sensitive information about survey costs be published and shared in a way that benefits all?
- How to distinguish initial development and transition costs from steady-state mixed mode costs, that is, how to amortize expenses on development of new modes?

Effects of mixed modes on measurement

If respondents answer a given question differently, depending on the mode in which they are interviewed, then data collected with mixed modes are not comparable. This can be a particular problem in longitudinal studies, where respondents might answer the same question in different modes over time. If the mode affects responses, then estimates of change are confounded with mode effects on measurement. Similarly, if different types of people choose to complete the interview in different modes, then estimates of group differences can be confounded with mode effects on measurement.

There are different possible reasons why respondents might give a different answer to the same question depending on the mode of interview (see Jäckle, Roberts, & Lynn, 2010). For example, the extent of interviewer involvement versus anonymity of the reporting situation can influence the respondent's willingness to disclose sensitive information; the extent of interviewer involvement can influence the amount of effort made by the respondent, and also the difficulty of the task for the respondent; contextual information, for example the characteristics of the interviewer, or how the question and answer options are presented to the respondent, can influence how the respondent processes the question. Based on the framework sketched out by Jäckle et al. (2010), Campanelli and Nicolaas (2013) compiled a literature review of empirical evidence of mode effects by question characteristics that are relevant to the risk of questions being answered differently across modes.

Drawing on this work, to predict the risk that a given questions might be answered differently in web than face-to-face, researchers at NatCen Social Research developed a coding frame for *Understanding Society* to predict the risk that a given question might be answered differently in web than face-to-face (d'Ardenne et al., 2017). They applied the coding frame to all questions in the wave 7-10 long-term content plan for *Understanding Society*. The risk factors were: the risks of interviewer effects (with binary indicators of whether fear of disclosure, social desirability responding, or positivity bias were likely); the risk of satisficing (whether the question wording was complex, whether it contained extra information such as definitions or interviewer instructions, whether the respondent had to compute the answer, consult documents, or whether it was an open question); and the risk of presentation effects (whether the question was a ranking task, a battery of scalar questions, the number of answer options, whether the question was a scale with mid-point, and whether there were hidden response options that the interviewer could code). Each of the 1,486 questions in the long-term content plan was coded independently by two coders. Risk ratings were derived from the coded indicators, as documented in (d'Ardenne et al., 2017). Among all items, 1.6% were coded as having a high risk of being answered differently in web and face-to-face, 20.1% as having a medium risk, and 78.3% as having low or no risk.

Most empirical tests of mode effects on measurement have been carried out in cross-sectional rather than longitudinal studies. Some mode combinations have been studied more than others, and there is, in particular, a paucity of evidence on the effects of combining web with interviewer administered modes in longitudinal studies, although both NCDS and the *Understanding Society* Innovation Panel have been used to examine the effects of mode on measurement. NCDS experimentally compared a sequential web and telephone design with a telephone only survey and found that 8% of 425 items tested showed significant differences (Brown, 2016b). In the *Understanding Society* Innovation Panel, comparing responses by mode of interview (i.e. not assignment) shows that there are differences between web and face-to-face responses for 18% of 479 items tested (Jäckle, 2016). Comparing responses by mode assignment (i.e. mixed versus single mode as in the NCDS analysis) showed differences for 3% of items. The drop in the number of significant differences suggests that there are large selection effects, that is, in the mixed mode group those who respond by web are very different from those who respond face-to-face. Once the face-to-face follow up of web non-respondents is included, the differences between the mixed mode group and face-to-face group are reduced. Using different statistical methods to identify the effect of mode on measurement while controlling for differences in who responds by web and who responds face-to-face suggests that respondents answered between 4% and 9% of items differently in web than they would have face-to-face. Combining the empirical estimates of mode effects in the Innovation Panel, with the risk coding by (d'Ardenne et al., 2017), suggests that the characteristics that put a question most at risk of being answered differently in web than face-to-face (controlling for all other coded risk indicators) are if it is a rating scale or if it has five or more response categories (Jäckle, 2016).

There are many unanswered key questions regarding the effects of mixed mode data collection on measurement, including:

- Do such differences affect substantive research conclusions such as sub-group comparisons or estimates of change?

- What advice should surveys give users about analysing mixed mode data?(see below)

- How to best identify measurement versus selection effects in testing for mode effects?
- How can we predict likely mode effects on measurement for different modes?
- How can we design survey questions to minimise the likelihood of differences in answers?

Consent to administrative data linkage

Many longitudinal studies link to data about their sample members from administrative records, to complement the breadth and detail of data collected in the survey (for a discussion see Calderwood & Lessof, 2009). For example, *Understanding Society* and the Millennium Cohort Study have linked to the English National Pupil Database, ALSPAC has also linked to health care records, and the English Longitudinal Study of Ageing (ELSA) to both health and benefits records. .

The regulations in the UK and many other countries require informed consent for data linkage: sample members must give the owner of administrative data permission to link their data to survey data. Data owners therefore largely determine the content and wording of consent questions. It is common to give respondents an information booklet about the planned linkage, illustrating for example what information the administrative data contain, the benefits of the linkage, how the data will be linked, how anonymity will be preserved, and how the data will be used. Some data owners accept verbal consent, recorded by the interviewer, as sufficient. Others require signatures.

As longitudinal studies are moving away from predominantly face-to-face interviewing to mixed mode data collection including telephone and web surveys, there are many practical questions about how best to implement consent questions (Thornby, Calderwood, Kotecha, Beninger, & Gaia, forthcoming). In telephone and web surveys, information leaflets can be sent out with the advance letter, instead of being handed over by the interviewer. Collecting signatures is however less feasible. In face-to-face and telephone surveys the respondent can give oral consent which the interviewer records in the questionnaire. In web the respondent provides consent by clicking the relevant response to the consent question.

Studies that have asked for consent to data linkage in different modes have found that consent rates are somewhat lower in telephone, and much lower in web, than face-to-face interviews. For example, in a pilot study for Next Steps that used a sequential web, telephone and face-to-face mixed mode design and asked for consent to link to administrative data held by seven different organisations, consent rates were between 1 and 7 percentage points lower with telephone than face-to-face for six of the organisations, but 1 percentage point higher for one. Consent rates by web respondents were however between 24 and 30 percentage points lower than face-to-face (Calderwood, 2016a). Similarly, in wave 9 of the Innovation Panel, consent to linkage with credit rating data held by the Financial Conduct Authority was 19 percentage points lower with web than face-to-face. In wave 8, consent to linkage with DWP data (asked only of new household members and respondents who had previously refused consent) was 34 percentage points lower among web than face-to-face respondents. Initial analyses of the Innovation Panel wave 8 data suggest that the lower consent rates in web are causes by the mode and not the result of different types of people answering in different modes (Burton, 2016): controlling for differences in sample characteristics by including socio-demographics as covariates in a regression, or using an instrumental variables approach to account for selection, the difference in consent rates is robust. This suggests respondents are less willing to give consent by web.

Previous studies of the role of interviewers have shown that there are large differences in the consent rates they obtain (e.g. Sakshaug, Couper, Ofstedal, & Weir, 2012; Sakshaug, Tutz, & Kreuter, 2013): interviewers who would themselves be willing to consent to data linkage achieve higher consent rates (Sakshaug et al., 2013), the number of consents the interviewer has achieved prior to the current request increases the likelihood of consent (Sakshaug et al., 2012; Sala, Burton, & Knies, 2012), but somewhat surprisingly, more experienced interviewers achieve lower rates (Korbmacher & Schroeder, 2013; Sakshaug et al., 2013; Sala et al., 2012).

Previous studies have also shown that respondents change their mind over time: in the U.S. Health and Retirement Study, 42% of respondents who had not given consent to linkage with Medicare data gave consent the second time they were asked. This suggests that people do not have strong fixed views on consent.

Key questions relating to informed consent in longitudinal mixed mode surveys include:

- Does the respondent's understanding of informed consent vary across modes?
- Does the mode affect the willingness of respondents to consent to data linkage?
- What is the role of the interviewer in obtaining informed consent?
- What can be done to simulate the interviewer's role in a web survey?
- Which methods can be used to increase informed consent in self-completion surveys?

Analysis of mixed mode data

If the modes used in a mixed mode survey lead to different sampling and non-sampling errors, this has implications for both for how the survey represents the population of interest, and how the concepts of interest are measured. Such differences between modes need to be taken into account when analysing data collected with mixed modes.

Mode-specific selective nonresponse has implications for adjustment methods such as weighting, imputation and covariate control (Lynn, 2016). Missing data patterns in longitudinal surveys are complex, typically involving unit nonresponse, instrument nonresponse, item nonresponse and wave nonresponse, any or all of which could be affected by mode. The assigned mode should not be informative of selection if modes are assigned at random, but may otherwise be informative. Evidence from *Understanding Society* suggests that response propensities can be dependent on the assigned data collection mode protocol and that the nature of the dependency varies greatly between sample members. Specifically, some sample members appear to be (considerably) more likely to participate in a web-first sequential mixed mode wave than in a face-to-face-only wave, while for others the reverse is true. This implies that for any survey that attempts to target different mode protocols to different sample members, an indicator of assigned mode, and interactions of that indicator with other auxiliary variables, should potentially be included in weighting and imputation models and/or as controls in substantive models. Furthermore, as the best variables for predicting response propensity may differ between mode protocols, thought should be given to the collection of mode-specific predictor variables in order to improve weighting and imputation models.

What guidance could be given to data users about how to account for measurement differences in mixed mode surveys? Ideally, the guiding principle is to assess things from the user's perspective. Users pondering their analyses will choose the variables and modelling procedures which best answer their substantive research questions. Survey documentation would therefore ideally include a list of variables at risk of mode effects that users can check. This list would indicate to users whether mode effects had been detected in exploratory analyses involving this variable, and the types of statistical analysis where these mode effects had unduly affected the results. The type of analysis is important because, for example, a mode effect on the standard deviation of a survey variable, but not on its mean, would not affect univariate summaries, but could affect multivariable or multivariate techniques like regression or structural equation modelling; whether the variable is treated as a predictor or outcome in the analysis is also important.

Further work that would provide useful guidance for data users would be to review and assess the major published approaches for mode-effect adjustment. This would include reviewing the assumptions underlying each method (for example, the simplest approach for regression models is to include a dummy variable to indicate which mode was used) and empirically assessing whether these assumptions generally hold or not. Key questions regarding the analysis of mixed mode data include:

- What guidance can be given to data users with different skill levels about how to analyse mixed mode data?

- How does weighting compare to other methods to adjust for differential non-response error between modes?

- Which methods can be used to account for differences in measurement between modes? For different types of variables and different types of statistical analyses?
- What guidance can be given to data users about how to carry out their own assessment of effects of mode on measurement?
- How to document known measurement differences?

Key research needs

Generally, as a field we have moved away from questioning whether we should use mixed mode data collection – to asking how best to design mixed mode surveys. The new questions include what is the best sequence and combination of modes for different populations and survey content? What are the best protocols for assigning respondents to modes and for moving them between modes during fieldwork? How can non-response bias and selectivity of different modes be addressed?

Sharing findings across studies is very important. However, given the large number of differences between studies in how mixed mode data collection is implemented (for example regarding respondent incentives, the number, content or mode in which reminders are sent, *etc*.) a key question is how to generalise findings about mode approaches and effects across studies?

Given the use of mixed mode data collection is here to stay we could consider how to exploit the opportunities for better quality of responses on some topics that web surveys create?

In adapting questionnaires for different modes, are there alternatives to single long interviews? For example modularisation with multiple short interviews instead of one longer interview? Converting an existing study to web, for example, tends to lead to a single long survey. In contrast, designing a new longitudinal study to be completed online would most likely result in a design with frequent short interviews.

Across the CLOSER Studies there is a wealth of research evidence and expertise in implementing mixed modes and their impact of subsequent survey quality, especially in a longitudinal context. Using the Total Survey Error Framework for considering quality issues ensure a holistic approach to quality is taken. As different longitudinal studies continue to explore mixed mode data collection, we should not only share findings with each other but also use experimentation to maximise learning possible.

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