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***Devil in the Detail: Appendix to Royal Statistical Society (RSS) COVID-19 Taskforce Statement on how efficient statistical method can glean intelligence from Test, Trace and Isolate (TTI),* officially known as Test & Trace**

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The RSS COVID-19 Task Force commends the efficient use of two statistical methods (record-linkage; random sampling), by which to learn about patterns of transmission of SARS-CoV-2 infection and the effectiveness of quarantine for two types of high-risk contacts whom TTI asks to "stay at home" because they are at an increased risk of contracting the disease, namely:

***(a) household-members of a symptomatic index case;***

***(b) external close contacts, identified by a symptomatic index case, who are traced and asked to self-isolate.***

### *a) Symptomatic index cases' quarantined household-members*

As TTI's week 4 (18-24 June) ended, the Department of Health and Social Care reported that there were 10,395 infected people (symptomatic index cases) who had been reached in weeks 1+2 and whose household members were quarantined for 14 days. These household members are likely to number at least 10,000. How many of them developed at least one of three key symptoms, had a swab-test, and tested RT-PCR positive for SARS-CoV-2 infection during their quarantine period (plus two days)?

*Using record-linkage,* TTI can report on how many of these quarantined high-risk household members had booked a swab-test and tested RT-PCR positive for SARS-CoV-2 infection during their 14-day quarantine period plus two days. At 2%, we'd expect 200; at 1%, we'd expect 100 swab-test positives. High time to find out?

Assuming that, for each index case, TTI holds information about household-size and composition (numbers of children; adults aged 18-44 years; 45-64 years; 65-74 years; seniors aged 75+ years), then within-household symptomatic RT-PCR positive-rate for quarantined household members can be compared by age-group; also potentially by gender, ethnicity and occupation.

***Unless TTI invokes random-sampling of the households of symptomatic index cases***, TTI will learn nothing about how early in the household's 14-day quarantine any of its members are swab-test positive (that is: irrespective of symptoms). *The random-sampling fraction can be varied informatively by household size or composition; and, if necessary, varied week-by-week to ensure that the effort entailed remains within-capacity.*

There is a strong parallel with the Office for National Statistics (ONS) Infection Survey which is household-based and returns weekly to participating households for members to complete a brief self-questionnaire about demography, symptoms and occupation (eg working at-home versus outside of the home).

But there are important differences: TTI-households are at substantially higher risk because there is a known symptomatic index patient within; and TTI-households would not be pre-notified about having been randomly selected to receive follow-up visits on one or two randomly (but purposefully) selected days within the household's 14-day quarantine period.

***At each randomly-timed visit to a sampled-TTI-index-household***, quarantined members would be invited to complete a brief self-questionnaire about demography, symptoms and occupation, as happens in ONS Infection Survey households, prior to swab-testing.

Within these representative households, each of which includes a symptomatic index case, intelligence can be gleaned on within-household transmission of SARS-CoV-2 infection (including to infected persons who have experienced no symptoms) by age, gender, ethnicity of household-members and by household size; and about adherence to quarantine from the percentage of quarantined household-members who are at-home on the random-swab-test-day when the household is visited.

***Randomly-timed but purposeful visits are achieved as follows.*** Each randomly-sampled-TTI-index-household is assigned their random test-day (or pair of days) to reflect current beliefs about household-members' prior probability of testing SARS-CoV-2 antigen positive. For example, if we believed that first five quarantined days accounted for half the likelihood of members' becoming swab-test positive, with the remaining 50% of our belief uniformly distributed across days 6 to 14, we might, for each randomly-chosen-TTI-index-household, select a random pair of swab-days such that the first falls within days 1-5 and the second within days 6-14.

Random sampling of TTI-index-households has other public health advantages as follows:

a.1 earlier diagnosis of any TTI-index-household-member who is swab-test positive (irrespective of symptoms) means earlier notification of ***their*** identified external close contacts;

a.2 discovering explanatory factors for household-members' odds on asymptomatic swab-test positivity in days 1-5 (versus days 6-14). Explanatory factors may include household size, gender, age 75+ years, ethnicity, deprivation, adherence to quarantine. Discoveries might suggest the need for additional shielding of vulnerable household-members or that symptomatic index cases should be self-isolated outside of the family-home.

a.3 updating of prior beliefs – in the light of swab-test positive results – about the likelihood of household-members' testing RT-PCR positive during quarantine days 1-5 versus 6-14.

### *b) Identified and reached external close contacts of symptomatic index cases*

In the first two weeks of TTI, approximately 90,000 external recent close contacts of symptomatic index cases were reached and asked to self-isolate. How many of them developed at least one of three key symptoms, had a swab-test, and tested RT-PCR positive for SARS-CoV-2 infection during their quarantine period (plus two days)? The expected number should be substantially greater than ONS's then-estimated rate of new infections (1 in 2,000 per week).

How many have there been? So much has been invested in TTI that answers are critically important for the public's trust in TTI and continued willingness to adhere to quarantine.

***Using record-linkage,*** TTI can report on how many of these quarantined high-risk external close contacts had booked a swab-test and tested RT-PCR positive for SARS-CoV-2 infection during their 14-day quarantine period plus two days. High time to find out?

Assuming that, for each quarantined external close contact, TTI holds demographical details (gender, age-group, ethnicity, deprivation quantile, occupation and household-size), then the symptomatic RT-PCR positive-rate for quarantined external close contacts can be compared by age-group; also by gender, ethnicity, deprivation, household-size and occupation.

***Unless TTI invokes random-sampling of the external close contacts of symptomatic index cases***, TTI will learn nothing about how early in close contacts' 14-day quarantine, they become swab-test positive (that is: irrespective of symptoms). *Random-sampling could be organized in 2-stages. For example, first select a random sample of TTI-index cases with sampling proportionate to their number of identified external close contacts; and, secondly, randomly-sample a fixed-proportion of their identified and reached external close contacts. Sampling fractions can also be varied informatively (according to*

*contact's demography) or, if necessary, varied week-by-week to ensure that the close-contact-swab-testing-effort remains within-capacity.*

***Randomly-timed but purposeful visits are achieved as follows.*** Each randomly-sampled-TTI-quarantined-close-contact is assigned their random test-day (or pair of days) to reflect current beliefs about their prior probability of testing SARS-CoV-2 antigen positive. For example, if we believed that first five quarantined days accounted for two-thirds of the likelihood of external close contacts' becoming swab-test positive, with the remaining one-third of our belief uniformly distributed across days 6 to 14, we might, for each randomly-chosen-TTI-close contact, select a random pair of swab-days such that days 1-5 each have probability 0.133 of being selected and days 6-14 each have probability of 0.037 of being selected.

Advantages from random sampling of TTI-quarantined-close-contacts align with those listed at a.1 to a.3.