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RESEARCH ARTICLE

REVISED **Could differences in implicit attitudes to sexual concurrency play a role in generalized HIV epidemics? [version 2; referees: 2 approved]**

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Abstract

Background: Sexual partner concurrency has been implicated in the genesis of generalized HIV epidemic in South Africa. Most South Africans, however, disapprove of concurrency in surveys. These surveys test individuals' explicit attitudes which are susceptible to a number of important biases such as the social desirability bias. Assessment of implicit cognitions have been found to be better predictors of behaviour in socially sensitive domains. We hypothesized that South Africans may have implicit attitudes more tolerant of concurrency than lower concurrency prevalence populations.

Methods: To test this hypothesis, we developed a concurrency-implicit association test (C-IAT) and compared the C-IATs of samples of South African and Belgian university students.

Results: We found a large and statistically significant difference in the C-IAT between the South Africans (D600-score = -0.009, indicating absence of preference for concurrency or monogamy) and Belgians (D600-score = 0.783, indicating a strong preference for monogamy; t-test = 13.3; $P < 0.0001$). The effect size measure, Cohen's d, was found to be 0.88, which is considered a large effect size in this field.

Conclusions: Our results are compatible with the thesis that differences in implicit attitudes to concurrency play a role in the genesis of generalised HIV epidemics.

Keywords
concurrency, HIV, sexual networks, implicit association

Open Peer Review

Referee Status: ✔✔

	Invited Referees	
	1	**2**
REVISED **version 2** published 18 Oct 2018	✔ report	✔ report
	↑	↑
version 1 published 17 May 2018	? report	? report

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REVISED **Amendments from Version 1**

A number of changes have been made as suggested by the reviewers:

The abstract conclusion has been changed as suggested.

The introduction has been expanded along the lines suggested.

Two new online files have been added:

- S1 IAT Test. Concurrency implicit association test.
- S2 Figures and words used in concurrency implicit association test.

Differences in C-IAT by gender are reported.

The discussion has been rewritten to make a number of points clearer.

See referee reports

</div>

Introduction

A higher prevalence of sexual partner concurrency, were an individual has a series of overlapping sexual partners at once, is one of the factors implicated in the genesis of generalized HIV epidemics in Southern and Eastern Africa[1–3]. Qualitative research from the region has argued that a tolerance of concurrency plays an important role in generating high concurrency rates[4–9]. A quantitative analysis of South African survey data, however, found that most men and women disapproved of concurrency[9]. This discrepancy may be partly explained by the way that the social desirability bias may affect the accuracy of self-reported data pertaining to socially sensitive topics such as sexual norms[10–14]. Respondents to surveys asking about attitudes to sexual partner concurrency may consider that the interviewer holds negative attitudes towards concurrency. They may therefore bias their reported attitudes towards concurrency towards that of the interviewer. Measures of implicit cognition assess cognitive processes less available to introspection and are thus less affected by these problems. Several studies have found implicit measures to be better predictors of behavior than explicit measures in these sensitive domains[10,13–15]. In a previous study, we developed a concurrency implicit association test (C-IAT) and tested it on a sample of 869 Belgian students[16]. The students revealed a strong implicit preference for monogamy as opposed to concurrency. No differences in C-IAT were found between men and women, but men who have sex with men and women who have sex with women were found to have a somewhat weaker implicit preference for monogamy than heterosexual men and women[16].

In this study, we compare the results from this Belgian study with those obtained from a similar sample of South African students. We assess: (i) if implicit and explicit norms towards concurrency differ between Belgian and South African university students, (ii) if the variation between these two populations involves a difference in behavior of 'core-groups' or general population shifts (iii) the correlation between implicit and explicit attitudes to concurrency and reporting that one has engaged in concurrency at both individual and population levels. Our rationale for exploring if the variation between these two populations involves a difference in behavior of 'core-groups' or general population shifts is based on the work of Rose and

others[17–19]. They argued that if one finds a bimodal distribution in behavior 'A' in population 'B' compared to a normal distribution in a comparison population 'C' then this finding would be compatible with the existence of a core-group with higher risk behaviour in population 'B' being responsible for some of the differences in behavior 'A' between the two groups. The concept of a 'core-group' is well established in the HIV field and typically refers to a subpopulation with a high level of sexual network connectivity (conferred by features such as partner concurrency and rate of partner change) that contributes disproportionately to the spread of HIV in that population[17].

Methods

Concurrency-IAT description

Implicit Association Tests (IATs) are reaction-time measures that tap implicit associations without requiring conscious introspection[20]. We developed a Concurrency-IAT (C-IAT) that measures the implicit associations that individuals hold towards concurrency in relation to monogamy. Our C-IAT was constructed using the attribute categories "positive/negative" and the target categories "monogamy/multiple partners." Participants had to categorize words as either positive or negative and pictures as either depicting two people in a monogamous relationship or two people of which one had another partner.

Our C-IAT consisted of five different blocks. The C-IAT was programmed in OpenSesame, an open source program for reaction time experiments, for the offline version that was used in English in South Africa[21]. The online Dutch-language IAT used in in Belgium was hosted on the Project Implicit® Web site. The full C-IATs as well as all the words and images used in their construction can be obtained from Kenyon et al.[16]

Explicit questionnaire

After completing the IAT the students were asked to complete a questionnaire pertaining to their sexual behavior and explicit attitudes to concurrency. These questions (variables they are intended to define) included: *How many sex partners do you have?* (Point prevalence concurrency); *Where there any other times in your life when you had more than one sex partner at a time?* (Life time concurrency). Three questions investigating explicit attitudes towards concurrency were assessed using a scale from 1 (strongly disagree) to 5 (strongly agree): *It's okay to have sex with others as long as your main partner does not find out?* (Concealed concurrency); *If you are in a sexual relationship with someone, it's okay to have sex with others as long as you are honest with your main partner about this?* (Liberalist concurrency); *If my main partner has other sex partners, it is okay for me to have other partners as well?* (Reactive concurrency)[22]. The questions used in this questionnaire are available from Kenyon et al.[16]

Procedure/protocol

All procedures were approved by the Institutional Review Board of the Institute of Tropical Medicine (Antwerp) and the Ethics Committees of the University of Antwerp and Rhodes University.

In both countries all students at the two participating Universities were eligible for study inclusion. In Belgium they were recruited via an email sent to the entire student body. This was not possible in South Africa and thus students were recruited via posters and word of mouth.

South Africa
All participants were tested independently either in the Department of Psychology or in a secure and quiet room at the Rhodes University library. After they had signed the informed consent form, students were first asked to perform the C-IAT behind a computer in the above mentioned locations. After students completed the C-IAT, they proceeded to answer the explicit, paper-and-pencil questionnaire measures.

Belgium
The entire protocol was conducted online. Students received a link to the study website via the recruitment e-mail. The first step on the study website was signing the informed consent form. They then completed the C-IAT, and after this the explicit questionnaire.

For both student populations, the IAT and explicit measures took between 15 and 20 minutes to complete.

Statistical analysis
D600-scores of the IAT were calculated according to the standard protocol suggested by Greenwald *et al.*[23,24] Scores usually vary between -2 and +2, indicating strong implicit preferences for concurrency and monogamy, respectively, with zero indicating absence of preference. The minimum response time was 400 ms, the maximum response time was 2500 ms. Any responses below this interval were omitted while any responses above this interval were recoded to 2500 ms. Incorrect answers got a penalty of 600 ms.

We compare the distributions of C-IAT (D600-scores) scores between Belgium and South Africa visually using histograms and statistically using t-tests for independent samples. In keeping with standard practice in this field, we used Cohen's d as a measure of effect size. Cohen's d was calculated by dividing the South African minus the Belgian mean difference D600 by the pooled standard deviation. Pearson's correlation was used to test the correlations between implicit and explicit attitudes as well as between these two and self-reported point-prevalence of concurrency. Chi-squared and t-tests were used to test differences between categorical and continuous variables. All analyses were repeated stratified by gender. There were differences by gender in self-reported concurrency and explicit (but not implicit) attitudes towards concurrency. These differences were, however, congruent between Belgium and South Africa and did not affect the results. As a result, only unstratified results are reported.

Population level analyses: Sexual norms and behaviors such as concurrency have been shown to vary between different sexual orientations[17,25–27]. This provided the rationale for using Spearman's correlation to assess the population level correlations between the point-prevalence of concurrency and intrinsic (mean D600) and extrinsic (mean values for each of the 3 variables considered separately) attitudes. The populations were defined according to self-reported sexuality by country and gender. Only populations with n > 10 were utilized for the analyses.

All analyses were performed in Stata 13 (StataCorp LP, College Station, TX, USA).

Results
A total of 869 students in Belgium and 70 in South Africa participated. The demographic characteristics of the populations are detailed in Table 1. The South African students reported more sexual partners in the past year than the Belgians (mean 3.5 and 1.4, respectively, $P < 0.001$), a higher point-prevalence of concurrency (38.7% and 3.0%, $P < 0.001$), ever having engaged in concurrency (61.5% and 22.2%, $P < 0.001$) and partner concurrency (50.8% and 16.9%, $P < 0.001$; Table 1).

IAT results
The IAT results for the South African and Belgian populations both approximated normal distributions with similar standard deviations (SD) = 0.40 and 0.42 respectively; Figure 1). There was a large and statistically significant difference in the C-IAT between the South Africans (D600-score = -0.009, indicating absence of preference for concurrency or monogamy) and Belgians (D600-score = 0.783, indicating a strong preference for monogamy; t-test = 13.3; $P < 0.0001$). The effect size measure, Cohen's d, was found to be 0.88 which is considered a large effect size in this field[10].

There was no difference in mean C-IAT score between men and women in Belgium (-0.81, SD = 0.39 and -0.78, SD = 0.40, respectively) or South Africa (0.05, SD = 0.46 and -0.01, SD = 0.40, respectively)

Explicit attitudes
The differences in implicit associations between countries were larger than those for explicit associations: South Africans were more pro-concealed-concurrency (d = 0.47), Belgians more pro-liberalist-concurrency (d = 0.27) and there was no difference in pro-reactive-concurrency (d = 0.03; Table 1).

Association between self-reported point-prevalence concurrency and implicit and explicit attitudes
Individual level: Self-reported concurrency behavior was slightly more strongly associated with explicit (r = 0.08 to 0.58) than implicit (r = 0.05 to 0.11) attitudes to concurrency by country (Table 2).

Population level: The prevalence of concurrency by sexual orientation was associated with the mean implicit attitude to concurrency (rho = 0.95, $P = 0.0004$, n = 8). The same relationship was present when the analysis was restricted to the Belgian students (rho = 0.87, $P = 0.024$, n = 6). The association between extrinsic attitudes and concurrency was not statistically significant (concealed concurrency: rho = 0.65, $P = 0.06$; liberal concurrency: rho = -0.50, $P = 0.171$; reactive concurrency: rho = -0.03, $P = 0.932$).

Table 1. Characteristics of study participants No. (%)/Mean [Standard Deviation].

	Belgium	South Africa
N	869	70
Sex		
Men	310 (37.1)	30 (34.5)
Women	526 (62.9)	39 (65.5)
Age - mean [SD]	22.94 [5.22]	22.09 [2.54]
Race/Ethnicity		***
African/Black	6 (0.7)	49 (70)
European/White	819 (97.6)	10 (14.3)
Asian	8 (1.0)	3 (2.9)
Other	6 (0.7)	9 (12.9)
Sexual Orientation		***
Heterosexual	733 (87.4)	52 (74.3)
WSW#	20 (2.4)	4 (5.7)
MSM#	32 (3.8)	12 (17.1)
Other	54 (6.4)	4 (2.9)
Sexual behaviour		
N partners last year – mean [SD]	1.40 [2.57]	3.5 [3.13]**
Current concurrency	25 (3.0)	24 (38.7)**
Ever concurrency	184 (22.2)	40 (61.5)**
Partner concurrency	139 (16.9)	33 (50.8)**
Explicit norms		
Concealed concurrency [SD]	1.39 [0.68]	2.04 [1.22]**
Liberalist concurrency [SD]	2.56 [1.27]	1.91 [1.09]**
Reactive concurrency [SD]	2.41 [1.23]	2.36 [1.26]
Implicit norms		
D600 [SD]	0.783 [0.406]	-0.009 [0.425]***

* P < 0.05, ** P < 0.001, *** P < 0.0001 (P-values are for comparisons between South Africa and Belgium).

WSW – Woman who has sex with women, MSM – Man who has sex with men

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Dataset 1. STable 1: Concurrency implicit association tests

http://dx.doi.org/10.5256/f1000research.14951.d203426

Discussion
The IAT results for the study populations in South Africa and Belgium were both normally distributed with a similar variance. Belgium's population curve was however relatively right-shifted. There was no evidence of a 'core high risk group' with a distribution outside of the Gaussian distribution in either country. This variation of distributions between different populations via right or left shifting the mean value (but retaining the same variance) mimics the findings of Rose and others for a wide variety of physical and mental health attributes and behaviors, including number of sex partners[17–19]. Rose's interpretation of this relationship was that populations do not tolerate 'excessive' variations in norms and behaviors and thus distributions of these characteristics move up and down as a whole[19].

Similarly, large differences in implicit cognition via shifting the mean value whilst retaining the same variance have been found between different groups in other studies[12,23,28]. One 34 country study, for example, found large differences in mean implicit gender-science stereotype scores between countries[28]. Of interest these mean IAT scores were found to be better predictors of national sex differences in math and science achievement than corresponding explicit attitudes. Culturally determined differences in implicit attitudes are thought to emerge during childhood or early adolescence as individuals participate in the custom complexes of their cultures[11,28,29]. Historical and anthropological analyses suggest that the shift from polygamy to monogamy in Southern Africa over the last 150 years did not reduce the number of partners men had. Non-marital and non-main partnerships were however driven underground[4,6,8,30]. This created the norm which - although heavily contested - maintains that it is acceptable for men to have 'kwapeni's' (secret lovers) as long as their main partner does not find out[5–7]. In our study, we found that 20.0% of South Africans versus 1.4% of Belgians agreed with this statement (P < 0.001). Because this is a sensitive topic it is possible that the IAT is providing an alternative measure of the acceptance of concurrency.

If our IAT results from South Africa are indeed reflective of a broader acceptance of concurrency than a population such as Belgium and this acceptance is causally linked to higher concurrency rates then the distribution of implicit responses to concurrency amongst South African students suggests that population level interventions would be required to address this issue. Current efforts targeting concurrency are largely focused on higher risk individuals which are unlikely to result in a shift in the population distribution in implicit attitudes to concurrency[5,27,31]. One approach may be to follow the Know Your Network concurrency reduction intervention which was shown to be feasible and acceptable in a rural Kenyan population[32].

A limitation with the line of reasoning outlined above is the low correlation found between self-reported concurrency and implicit attitudes to concurrency. This may be because the implicit attitudes play little or no role in driving high concurrency rates. Alternatively, the C-IAT may constitute an important marker of a population-wide greater tolerance of concurrency which broadly enables higher concurrency rates but that other specific risk factors then determine which individuals will engage in concurrency[33]. We found some support for this latter interpretation in the form of a population level correlation between implicit attitudes towards concurrency and the practice thereof.
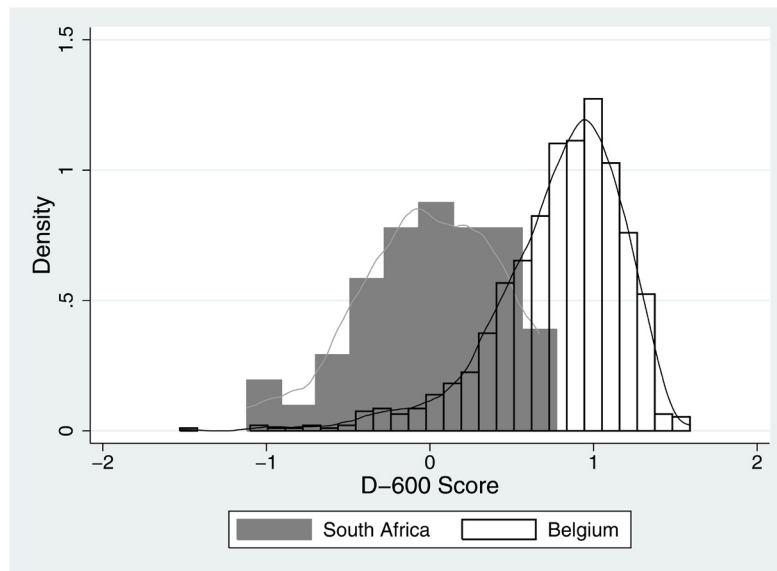
Figure 1. Distributions of D600 scores for South African and Belgian students (Positive and negative scores indicate preferences for monogamy and concurrency respectively).

Table 2. Pearson's correlations between implicit and explicit attitudes towards concurrency.

	Belgium	South Africa
N	869	70
Correlation point-concurrency vs IAT[#]	0.11**	0.05
Correlation point-concurrency vs explicit norms		
Concealed concurrency	0.18**	0.58**
Liberalist concurrency	0.13**	0.55**
Reactive concurrency	0.08*	0.49**
Correlation IAT[#] vs explicit norms		
Concealed concurrency	0.17**	0.18
Liberalist concurrency	0.20**	0.22
Reactive concurrency	0.19**	0.11

* P < 0.05, ** P < 0.001, *** P < 0.0001
# IAT - Implicit Association Tests

What this suggests is that there is a broader acceptance of concurrency in South Africa at an implicit level. This might play a role in determining the higher prevalence of concurrency in South Africa. Other factors such as previous experience of partner concurrency may then determine which specific individuals engage in concurrency[34,35]. Further study limitations include: a small sample size in South Africa; only samples from two countries were included in the study; and there were slight differences in how participants were recruited and tested.

In South Africa, explicit questionnaires were completed on paper and pencil and the IAT was run offline. In Belgium, both the explicit questionnaire and IAT were offered online and could be completed from home. Respondents were self-selected and thus the samples cannot be regarded as representative of the entire university student or national populations. Finally, in the Belgian sample the nature of the web-based IAT meant that we could not exclude the possibility of multiple participations by respondents.

Data availability

Dataset 1: STable 1: Concurrency implicit association tests 10.5256/
f1000research.14951.d203426[36]

Grant information

Supplementary material
Supplementary File 1- IAT Test

Concurrency implicit association test.

Click here to access the data

Supplementary File 2- **Figures and words used in concurrency implicit association test.**

Click here to access the data

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Open Peer Review

Current Referee Status: ✓ ✓

Version 2

Referee Report 06 November 2018

https://doi.org/10.5256/f1000research.18230.r39627

✓ **Maddalena Marini**

Center for Translational Neurophysiology, Italian Institute of Technology (IIT), Ferrara, Italy

Abstract
I see no changes in the conclusions of the abstract.

Introduction
Can authors discuss in the manuscript also the rationale and relevance of investigating the correlation between implicit and explicit attitudes at the individual and population levels as requested in my first report?

Methods
In the new online files I see no description of the IAT procedure but only stimuli used in the task. Can authors describe the IAT procedure in the text of the manuscript?

Statistical analysis and results
I suggest authors to provide the additional information about the computation of the D and explicit scores also in the text of the manuscript. In particular, since the sample size of the two groups was very different (869 vs. 70), how they calculated the Cohen's d (and the associated pooled standard deviation).

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Referee Report 06 November 2018

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✓ **Hsun-Ta Hsu**

School of Social Work, University of Missouri, Columbia, MO, USA

I appreciate the authors addressing the comments I had; I do not have further comments.

Competing Interests: No competing interests were disclosed.

Referee Expertise: homelessness; sexual risks; health promotion

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Referee Report 05 October 2018

? **Maddalena Marini**

Center for Translational Neurophysiology, Italian Institute of Technology (IIT), Ferrara, Italy

The present study investigates the explicit and implicit attitudes to sexual concurrency in a sample of Belgium and South African students. Explicit attitudes were measured using self-reported items, while implicit attitudes were assessed by means of an Implicit Association Test (IAT). At the explicit level, both groups reported negative attitudes towards sexual concurrency, while at the implicit level, strong implicit preferences for monogamy were found only among Belgian students. No implicit preference between monogamy and multiple partners were indeed observed among South African students.

General Comments:
The aim of this study is very interesting because it highlights an implicit attitude to sexual concurrency that may underlie the origin of generalized HIV epidemic in South Africa. However, I have some reservations about the methodology, the statistical analysis, and the conclusions that prevent me from supporting the publication of this manuscript in its present form.

Abstract
1. Authors state that their results "are compatible with the thesis that differences in implicit attitudes to concurrency play a role in the genesis of generalized HIV epidemics". Since the present study did not investigate directly the relationship between implicit attitudes and HIV epidemic, I would suggest to be more careful in drawing these conclusions.

Introduction
1. On page 3, the authors state: "(ii) if the variation between these two populations involves a difference in behavior of 'core-groups' or general population shifts (iii) the correlation between implicit and explicit attitudes to concurrency and reporting that one has engaged in concurrency at both individual and population levels". What did the authors exactly mean with 'core-group'? Why is it important to evaluate the correlation between implicit and explicit attitudes at the individual and population levels? I suggest the authors to discuss more in details these points, their rationale and relevance.

Methods
1. For the IAT structure and its stimuli, authors refer to one of their previous publications[1]. However, I would recommend the authors to provide a description of the IAT procedure as well as examples of stimuli used in their study, so that readers can better understand this instrument.

Statistical analysis
1. Could the authors please provide additional information on how they computed the D-scores?
2. In addition, it would great if the authors could also provide more details on the procedure used for individual and population level analyses.

Results
1. The authors state that "there was no difference between C-IAT results by gender in either country (data shown)". I suggest the authors to report also the relative statistics.
2. Could the authors please provide additional information on how they computed the Cohen's d scores reported in the results of implicit and explicit attitudes?
3. The r range of explicit measures reported in the text and in Table 2 is different. In the text, it is from 0.13 to 0.58, while in Table 2 it is from 0.08 to 0.58. Please clarify.

Discussions
1. Could the authors please clarify the following statement reported on page 6 "If this is the case and this acceptance is causally linked to higher concurrency rates then the distribution of implicit responses to concurrency amongst South African students suggests that population level interventions would be required to address this issue"?
2. The authors state "the C-IAT may constitute an important marker of a population-wide greater tolerance of concurrency which broadly enables higher concurrency rates but that other specific risk factors then determine which individuals will engage in concurrency". Could they please elaborate on that?

Minor comment:
I would suggest the authors to read carefully the text as it presents several typos and problems in the grammatical structure.

References

1. Kenyon C, Wolfs K, Osbak K, van Lankveld J, Van Hal G: Implicit attitudes to sexual partner concurrency vary by sexual orientation but not by gender—A cross sectional study of Belgian students. *PLOS ONE*. 2018; **13** (5). Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 12 Oct 2018

Chris Kenyon, Institute of Tropical Medicine, Antwerp, Belgium

General Comments:
The aim of this study is very interesting because it highlights an implicit attitude to sexual concurrency that may underlie the origin of generalized HIV epidemic in South Africa. However, I have some reservations about the methodology, the statistical analysis, and the conclusions that prevent me from supporting the publication of this manuscript in its present form.

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1. Authors state that their results "are compatible with the thesis that differences in implicit attitudes to concurrency play a role in the genesis of generalized HIV epidemics". Since the present study did not investigate directly the relationship between implicit attitudes and HIV epidemic, I would suggest to be more careful in drawing these conclusions.

Reply:
The abstract conclusion has been changed to the following:
South African students were found to have less of a preference for monogamy than Belgian students.

Introduction
1. On page 3, the authors state: "(ii) if the variation between these two populations involves a difference in behavior of 'core-groups' or general population shifts (iii) the correlation between implicit and explicit attitudes to concurrency and reporting that one has engaged in concurrency at both individual and population levels". What did the authors exactly mean with 'core-group'? Why is it important to evaluate the correlation between implicit and explicit attitudes at the individual and population levels? I suggest the authors to discuss more in details these points, their rationale and relevance.

Reply:
The following text has been added to the end of the introduction to make this clearer:
Our rationale for exploring if the variation between these two populations involves a difference in behavior of 'core-groups' or general population shifts is based on the work of Rose and others [25]– [27]. They argued that if one finds a bimodal distribution in behavior 'A' in population 'B' compared to a normal distribution in a comparison population 'C' then this finding would be compatible with the existence of a core-group with higher risk behaviour in population 'B' being responsible for some of the differences in behavior 'A' between the two groups. The concept of a 'core-group' is well established in the HIV field and typically refers to a subpopulation with a high level of sexual network connectivity (conferred by features such as partner concurrency and rate of partner change) that contributes disproportionately to the spread of HIV in that population . Kenyon CR, Tsoumanis A, Schwartz IS: A population's higher-risk sexual behaviour is associated with its average sexual behaviour-An ecological analysis of subpopulations in Ethiopia, Kenya, South Africa, Uganda and the United States. *Epidemics.* 2016;15:56–65. 27266849 10.1016/j.epidem.2016.02.002

Methods
1. For the IAT structure and its stimuli, authors refer to one of their previous publications [1]. However, I would recommend the authors to provide a description of the IAT procedure as

well as examples of stimuli used in their study, so that readers can better understand this instrument.

Reply:

This information has been provided as a two new online files:

S1 IAT Test. Concurrency implicit association test.

S2 Figures and words used in concurrency implicit association test.

Statistical analysis

1. Could the authors please provide additional information on how they computed the D-scores?

Reply:

The D600 scores were calculated as follows:

D600-scores of the IAT were calculated according to the standard protocol suggested by Greenwald et al. Reaction times of the second target-attribute combination were subtracted from the first combination, correcting for combination sequence, and divided by the pooled standard deviation of all practice and test phases. Scores usually vary between -2 and +2, with high scores indicating strong implicit preferences for monogamy and concurrency, respectively, with zero indicating absence of preference, positive scores indicating a positive implicit association with concurrency (and a negative association with monogamy), and negative scores indicating a negative implicit association with concurrency (and a positive association with monogamy). Before calculating the D600 score, the minimum response time was set at 400 ms, the maximum response time at 2500ms. Any responses below this interval were omitted while any responses above this interval were recoded to 2500 ms. Reaction times of incorrect answers were raised using a penalty of 600 ms.

1. In addition, it would great if the authors could also provide more details on the procedure used for individual and population level analyses.

Reply:

For the population level analyses, Spearman's correlation was used to assess the population level correlations between the point-prevalence of concurrency and intrinsic (mean D600) and extrinsic (mean values for each of the 3 variables considered separately) attitudes. The populations were defined according to self-reported sexuality by country and gender. Only populations with n > 10 were utilized for the analyses.

For the individual level analyses, the statistical analytical strategy used is described in the methods:

We compare the distributions of C-IAT (D600-scores) scores between Belgium and South Africa visually using histograms and statistically using t-tests for independent samples. In keeping with standard practice in this field, we used Cohen's d as a measure of effect size. Cohen's d was calculated by dividing the South African minus the Belgian mean difference D600 by the pooled standard deviation. Pearson's correlation was used to test the correlations between implicit and explicit attitudes as well as between these two and self-reported point-prevalence of concurrency. Chi-squared and t-tests were used to test differences between categorical and continuous variables. All analyses were repeated stratified by gender. There were differences by gender in self-reported concurrency and explicit (but not implicit) attitudes towards concurrency. These differences were, however, congruent between Belgium and South Africa and did not affect the results. As a result, only unstratified results are reported.

Results

1. The authors state that "there was no difference between C-IAT results by gender in either country (data shown)". I suggest the authors to report also the relative statistics.

Reply:

This information has been added to the second paragraph of the results as follows:

There was no difference in mean C-IAT score between men and women in Belgium (-0.81, SD = 0.39 and -0.78, SD = 0.40, respectively) or South Africa (0.05, SD = 0.46 and -0.01, SD = 0.40, respectively)

1. Could the authors please provide additional information on how they computed the Cohen's d scores reported in the results of implicit and explicit attitudes?

Reply:

Cohen's d was calculated by dividing the South African minus the Belgian mean difference D600 by the pooled standard deviation.

1. The r range of explicit measures reported in the text and in Table 2 is different. In the text, it is from 0.13 to 0.58, while in Table 2 it is from 0.08 to 0.58. Please clarify.

Reply:

Thank you for pointing this out. It has been corrected to 0.08 to 0.58 in the text.

Discussions

1. Could the authors please clarify the following statement reported on page 6 "If this is the case and this acceptance is causally linked to higher concurrency rates then the distribution of implicit responses to concurrency amongst South African students suggests that population level interventions would be required to address this issue"?

Reply:

We have rewritten this section to make it clearer. It now reads:

If our IAT results from South Africa are indeed reflective of a broader acceptance of concurrency than a population such as Belgium and this acceptance is causally linked to higher concurrency rates then the distribution of implicit responses to concurrency amongst South African students suggests that population level interventions would be required to address this issue.

1. The authors state "the C-IAT may constitute an important marker of a population-wide greater tolerance of concurrency which broadly enables higher concurrency rates but that other specific risk factors then determine which individuals will engage in concurrency". Could they please elaborate on that?

Reply:

The following text has been added to this section to make it clearer:

What this suggests is that there is a broader acceptance of concurrency in South Africa at an implicit level. This might play a role in determining the higher prevalence of concurrency in South Africa. Other factors such as previous experience of partner concurrency may then determine which specific individuals engage in concurrency .

Minor comment:

I would suggest the authors to read carefully the text as it presents several typos and problems in the grammatical structure.

Reply:
The paper has been re read and a number of typos corrected.

Competing Interests: We have no conflicts of interest

Referee Report 06 June 2018

Hsun-Ta Hsu
School of Social Work, University of Missouri, Columbia, MO, USA

Introduction
1. I would recommend the authors do a final review of the paper to ensure it is free of grammatical errors and typos (e.g., in the first sentence in the introduction, "were" should be "where").
2. The authors stated: "This discrepancy may be partly explained by the way that the social desirability bias may affect the accuracy of self-reported data pertaining to socially sensitive topics such as sexual norms." I would like to see more elaboration as it pertains to concurrency.
3. The statement regarding the findings of applying C-IAT on Belgium students is great. Since one of the study purposes is to identify the discrepancies between implicit and explicit norms between Belgium and South African participants, I would like to see the authors add their findings on whether there were discrepancies regarding explicit and implicit concurrency norms in their previous Belgium research. Currently, the authors only provide information regarding implicit norms of concurrency among Belgium students.
4. It would be great if the authors would discuss their rationale for comparing South African and Belgium students.
5. Also, it would be beneficial if the authors could provide more justification for the study aims (e.g., why look at shifts and correlations of the norms).
6. Finally, the rationale of looking at college students should also be provided. Is it because they more likely to be sexually active? More likely to engage in concurrency? Or, more likely to at risks of HIV/STIs?
Method
1. Information regarding validity and reliability of the measurements used may be needed.
2. The authors mentioned that they recruited participants who were "similar" to participants in the Belgium study for the comparison of implicit and explicit norms. How did the authors determine similarity when recruiting participants in South Africa? Since they are all college students, I am assuming their age might be similar? How about the concentrations/majors?
3. More info regarding sampling may be needed. For example, how many students were approached? What was the refusal rate?
4. The measurements were used to measure implicit and explicit norms. Why would there be incorrect answers? Could the authors provide some examples?
Results
1. Some of the numbers stated in the text do not match the tables. For example, the author stated: "Self-reported concurrency behavior was slightly more strongly associated with explicit (r = 0.13 to 0.58) than implicit (r = 0.05 to 0.11) attitudes to concurrency by country." But, in Table 2, it seems that the correlation of explicit and concurrency behavior is 0.08-0.58. The authors might want to review the numbers.
Discussion
1. The authors provide great information in that based on the finding, current efforts of targetting high-risk

individuals may not be enough. Could the authors provide more information on, specifically, what may be the potential approach to address concurrency, especially targetting implicit attitudes on a population level?

2. In the discussion section, the authors seemed to imply that the findings may apply to population level. However, given the sampling strategy, I am not sure if such argument may be the case. Could the authors provide more evidence or explanation?

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 20 Jun 2018

Chris Kenyon, Institute of Tropical Medicine, Antwerp, Belgium

Dear Dr Hsu

Thank you for your useful suggestions and comments, which we respond to below:

Introduction
1. I would recommend the authors do a final review of the paper to ensure it is free of grammatical errors and typos (e.g., in the first sentence in the introduction, "were" should be "where").

Reply:
This will be done in the next version.
2. The authors stated: "This discrepancy may be partly explained by the way that the social desirability bias may affect the accuracy of self-reported data pertaining to socially sensitive topics such as sexual norms." I would like to see more elaboration as it pertains to concurrency.

Reply:
This will be done in the next version of the paper.

3. The statement regarding the findings of applying C-IAT on Belgium students is great. Since one of the study purposes is to identify the discrepancies between implicit and explicit norms between Belgium and South African participants, I would like to see the authors add their findings on whether there were discrepancies regarding explicit and implicit concurrency norms in their previous Belgium research. Currently, the authors only provide information regarding implicit norms of concurrency among Belgium students.

Reply:
These results are provided in detail at:
Kenyon CR, Wolfs K, Osbak K, et al.: Implicit attitudes to sexual partner concurrency vary by sexual orientation but not by gender - a cross sectional study of Belgian students. PLoS One. (In Press). 2018; 13(5): e0196821.

4. It would be great if the authors would discuss their rationale for comparing South African and Belgium students.

Reply:
This was based on opportunity sampling related to the institutions/countries where the authors work.
5. Also, it would be beneficial if the authors could provide more justification for the study aims (e.g., why look at shifts and correlations of the norms).

Reply:
This will be done in the next version of the paper.

6. Finally, the rationale of looking at college students should also be provided. Is it because they more likely to be sexually active? More likely to engage in concurrency? Or, more likely to at risks of HIV/STIs?

Reply:
Concurrency and STI rates are particularly high in this age group.
Method
1. Information regarding validity and reliability of the measurements used may be needed.

Reply:
As we note in this paper this was assessed in the previous paper we refer to:
Kenyon CR, Wolfs K, Osbak K, et al.: Implicit attitudes to sexual partner concurrency vary by sexual orientation but not by gender - a cross sectional study of Belgian students. PLoS One. (In Press). 2018; 13(5): e0196821.
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Repy:
We did not collect information as to the subjects they were studying.

3. More info regarding sampling may be needed. For example, how many students were approached? What was the refusal rate?

Reply:
We do not have this data. The recruitment method used is detailed in the section:
In both countries all students at the two participating Universities
were eligible for study inclusion. In Belgium they were recruited
via an email sent to the entire student body. This was not possible
in South Africa and thus students were recruited via posters and
word of mouth.
4. The measurements were used to measure implicit and explicit norms. Why would there be incorrect answers? Could the authors provide some examples?

Reply:
The reference to "incorrect answers" on the IAT test refers to misclassifying an image or word during the IAT test e.g. placing an image of monogamy in the concurrency section.
Results
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Reply:
Thank you for pointing out this error which will be corrected in the next version of the paper.
Discussion
1. The authors provide great information in that based on the finding, current efforts of targeting high-risk individuals may not be enough. Could the authors provide more information on, specifically, what may be the potential approach to address concurrency, especially targetting implicit attitudes on a population level?

Reply:
This paragraph has now been expanded with the following text to address this question:
Current efforts targeting concurrency are largely focused on higher risk individuals which are unlikely to result in a shift in the population distribution in implicit attitudes to concurrency [5, 27, 31].
One approach may be follow the Know Your Network concurrency reduction intervention which was shown to be feasible and acceptable in a rural Kenyan population (**Knopf A, et al.** "This is the medicine:" A Kenyan community responds to a sexual concurrency reduction intervention. *Social Science & Medicine* 2014; **108**: 175-184).

2. In the discussion section, the authors seemed to imply that the findings may apply to population level. However, given the sampling strategy, I am not sure if such argument may be the case. Could the authors provide more evidence or explanation?

Reply:
This is true. In the new version we have changed this claim to the following weaker claim:
We found weak support for this latter interpretation in the form of a population level correlation between implicit attitudes towards concurrency and the practice thereof. This is however based on a small number of samples and this finding should be regarded as tentative.

Competing Interests: No competing interests

Author Response 12 Oct 2018

Chris Kenyon, Institute of Tropical Medicine, Antwerp, Belgium

Thank you for your useful suggestions and comments, which we respond to below:

Introduction
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2. The authors stated: "This discrepancy may be partly explained by the way that the social desirability bias may affect the accuracy of self-reported data pertaining to socially sensitive topics such as sexual norms." I would like to see more elaboration as it pertains to concurrency.

Reply:
The following text has been added to make this clearer:
Respondents to surveys asking about attitudes to sexual partner concurrency may consider that the interviewer holds negative attitudes towards concurrency. They may therefore bias their reported attitudes towards concurrency towards that of the interviewer.

3. The statement regarding the findings of applying C-IAT on Belgium students is great. Since one of the study purposes is to identify the discrepancies between implicit and explicit norms between Belgium and South African participants, I would like to see the authors add their findings on whether there were discrepancies regarding explicit and implicit concurrency norms in their previous Belgium research. Currently, the authors only provide information regarding implicit norms of concurrency among Belgium students.

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These results are provided in detail at:
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4. It would be great if the authors would discuss their rationale for comparing South African and Belgium students.

Reply:
This was based on opportunity sampling related to the institutions/countries where the authors work. Various studies have noted concurrency prevalences to be relatively low in Western Europe and relatively high in South Africa [1-3].

5. Also, it would be beneficial if the authors could provide more justification for the study aims (e.g.,

why look at shifts and correlations of the norms).

Reply:

The following text has been added to the end of the introduction to make this clearer: Our rationale for exploring if the variation between these two populations involves a difference in behavior of 'core-groups' or general population shifts is based on the work of Rose and others [25– 27]. They argued that if one finds a bimodal distribution in behavior 'A' in population 'B' compared to a normal distribution in a comparison population 'C' then this finding would be compatible with the existence of a core-group with higher risk behaviour in population 'B' being responsible for some of the differences in behavior 'A' between the two groups. The concept of a 'core-group' is well established in the HIV field and typically refers to a subpopulation with a high level of sexual network connectivity (conferred by features such as partner concurrency and rate of partner change) that contributes disproportionately to the spread of HIV in that population . Kenyon CR, Tsoumanis A, Schwartz IS: A population's higher-risk sexual behaviour is associated with its average sexual behaviour-An ecological analysis of subpopulations in Ethiopia, Kenya, South Africa, Uganda and the United States. *Epidemics.* 2016;15:56–65. 27266849 10.1016/j.epidem.2016.02.002

In addition, we have explained the rationale for looking at shifts in C-IAT between Belgium and South Africa in the following text in the discussion:
The IAT results for the study populations in South Africa and Belgium were both normally distributed with a similar variance. Belgium's population curve was however relatively right-shifted. There was no evidence of a 'core high risk group' with a distribution outside of the Gaussian distribution in either country. This variation of distributions between different populations via right or left shifting the mean value (but retaining the same variance) mimics the findings of Rose and others for a wide variety of physical and mental health attributes and behaviors, including number of sex partners [25– 27] . Rose's interpretation of this relationship was that populations do not tolerate 'excessive' variations in norms and behaviors and thus distributions of these characteristics move up and down as a whole [27] .

As far as assessing the correlation between C-IAT and explicit norms is concerned, this is a standard assessment in this type of IAT research. We have provided this rationale in the following text in the discussion:

A limitation with the line of reasoning outlined above is the low correlation found between self-reported concurrency and implicit attitudes to concurrency. This may be because the implicit attitudes play little or no role in driving high concurrency rates. Alternatively, the C-IAT may constitute an important marker of a population-wide greater tolerance of concurrency which broadly enables higher concurrency rates but that other specific risk factors then determine which individuals will engage in concurrency [32] . We found some support for this latter interpretation in the form of a population level correlation between implicit attitudes towards concurrency and the practice thereof.

6. Finally, the rationale of looking at college students should also be provided. Is it because they more likely to be sexually active? More likely to engage in concurrency? Or, more likely to at risks

of HIV/STIs?

Reply:
Concurrency and STI rates are particularly high in this age group [3, 4].

Method
1. Information regarding validity and reliability of the measurements used may be needed.

Reply:
As we note in the current paper the assessment of validity and reliability were perfomed in the previous paper reporting the development of the C-IAT:

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Repy:
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3. More info regarding sampling may be needed. For example, how many students were approached? What was the refusal rate?

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Reply:
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Results
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Thank you for pointing out this error which has been corrected in the new version of the paper.

Discussion
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Reply:
This paragraph has now been expanded with the following text to address this question: Current efforts targeting concurrency are largely focused on higher risk individuals which are unlikely to result in a shift in the population distribution in implicit attitudes to concurrency [5, 27, 31] . One approach may be follow the Know Your Network concurrency reduction intervention which was shown to be feasible and acceptable in a rural Kenyan population (Knopf A, et al. "This is the medicine:" A Kenyan community responds to a sexual concurrency reduction intervention. *Social Science & Medicine* 2014; 108: 175-184).

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References

1. Leridon H, van Zessen G, Hubert M. The Europeans and their sexual partners. *Sexual behaviour and HIV/AIDS in Europe: Comparisons of national surveys* 1998: 165-96.
2. Kenyon C, Buyze J, Colebunders R. HIV prevalence by race co-varies closely with concurrency and number of sex partners in South Africa. *PLoS One* 2013; **8**: e64080.
3. Mah T. Prevalence and correlates of concurrent sexual partnerships among young people in South Africa. *Sex Transm Dis* 2010; **37**: 105-8.
4. Maughan-Brown B, Kenyon C, Lurie MN. Partner Age Differences and Concurrency in South Africa: Implications for HIV-Infection Risk Among Young Women. *AIDS and Behavior* 2014: 1-8.

Competing Interests: We have no conflicts of interest

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