Involuntary mental replay of music improves memory for musical sequence knowledge

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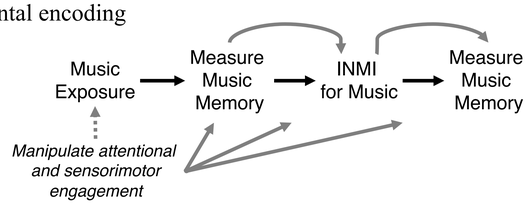
Introduction

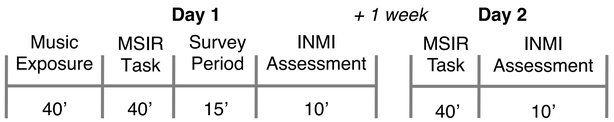
- *Spontaneous memory reactivation* plays an important role in consolidation
- *Repetitive involuntary musical imagery* (INMI; aka "earworm" or having a tune "stuck in one's head") is a common example of spontaneous cognition
- The role of INMI in the consolidation of musical memories remains unknown

Hypothesis A: Increased sensorimotor and attentional engagement during music exposure will facilitate incidental encoding resulting in more accurate music memory and more frequent INMI episodes

Hypothesis B: More frequent INMI episodes produce more accurate music memory



Methods



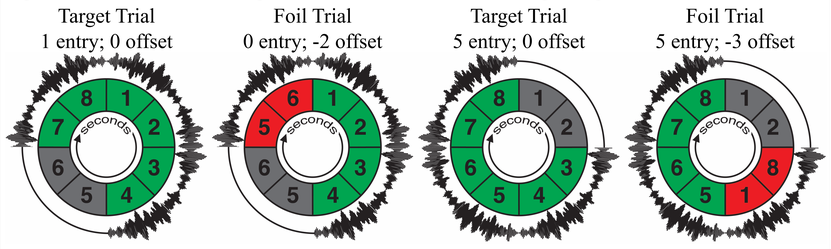
Experiment	# Participants	# Unique Loops	# Loop Exposures
1	31	12	16
2	30	12	16
3	30	9	24

Stimuli: 8-second music loops consisting of 4 instruments available as Apple Loops (Apple, Inc., Cupertino, CA); composed in C-major, 4/4 meter, 120 bpm tempo; sets of 3 loops were combined into 1-minute-36-second-long soundtracks, with each loop repeating for 32 seconds.

Music Exposure: Each soundtrack repeated multiple times during the task condition with which it was paired, and a single soundtrack was withheld but later included in the MSIR tasks (Novel condition; NOV).

Music Exposure Task	Exp.	Attentional Focus	Sensorimotor Engagement
Visual Deviant Detection (VDD) — spacebar	1,2	visuospatial sequence	-
Auditory Deviant Detection (ADD) — spacebar	1,2	music sequence	-
Free-Form Tapping (FTP) — B/M	1,2,3	music sequence	music sequence
Serial Reaction Time Task (SRT) — index, middle, ring, pinky	3	visuospatial sequence	visuospatial sequence

Musical Sequence Imagery Recognition (MSIR) : Report with a "Yes/No" response, whether the sound resumes after the silent blank at the correct location in the loop. To achieve above chance performance participants had to accurately imagine the missing part of the loop. Each loop was presented 8 times, 4 as a target and 4 as a foil, thus allowing for the calculation of a d' score on a per-loop basis.



Survey Period: Opportunity for participants to experience INMI for the loops to which they had just been exposed. Also expected INMI for loops outside of the laboratory, between experiment sessions.

INMI Assessment: Simple loop recognition task: participants heard each loop and an equal number of novel loops serving as foils. If loop was recognized on Day 1, participants were asked to estimate the frequency of INMI episodes experienced and to report the spatiotemporal context of the episode.

Results

INMI Phenomenology

Day 1 response proportions

87%, 90%, and 87% of participants experienced INMI for at least 1 loop during the Day 1 session in Exp. 1-3, respectively.

Exp.	n IRMI	INMI Frequency					INMI Vividness			
		1-20%	21-40%	41-60%	61-80%	81-100%	Slightly Vivid	Mod. Vivid	Very Vivid	As Vivid As Actual Sound
1	177	.58	.21	.11	.08	.02	.33	.30	.19	.18
2	163	.60	.21	.13	.05	.01	.30	.39	.23	.07
3	126	.67	.23	.06	.05	.00	.37	.35	.18	.10

Majority of INMI happened during break periods prior to and/or during performance of the MSIR task.

Exp.	Exposure	MSIR	Survey	2 periods	3 periods	No Period
1	.23	.77	.47	.25	.12	.2
2	.26	.84	.51	.31	.17	.3
3	.39	.83	.50	.35	.20	.2

Day 2 response proportions

77%, 80%, and 87% of participants experienced INMI for at least 1 loop during the 1-week delay period in Exp. 1-3, respectively.

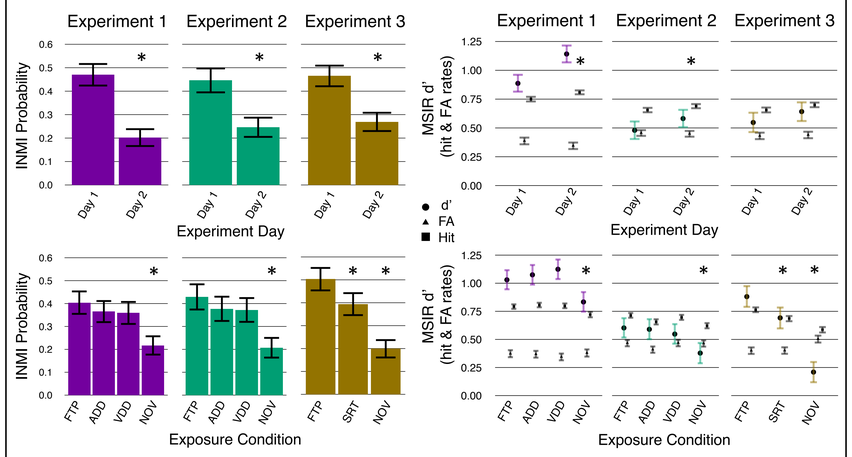
Exp.	n INMI	INMI Frequency					INMI Vividness				INMI Duration				
		On a single day	On two days	On three days	On four days	On at least five days	Slightly Vivid	Mod. Vivid	Very Vivid	As Vivid As Actual Sound	Less than 10 min.	Btw. 10 min. and half an hour	Btw. half and 1 hour	Btw. 1 and 3 hours	More than 3 hours
1	78	.74	.21	.04	.01	.00	.23	.44	.23	.10	.87	.13	.00	.00	.00
2	91	.75	.21	.01	.00	.03	.31	.42	.21	.07	.85	.14	.01	.00	.00
3	74	.80	.15	.04	.01	.00	.32	.38	.20	.09	.88	.12	.00	.00	.00

Majority of INMI occurred while participants were traveling to and from the lab and during periods of mind wandering. Participants failed to recall the trigger of most episodes.

Exp.	INMI Context							INMI Triggers			
	Recent Part.	Comm.	School work	Chores	Idling	Other	No Recall	Study Rem.	Other Media	Other	No Recall
1	.23	.27	.18	.09	.13	.09	.23	.08	.29	.03	.55
2	.30	.25	.11	.03	.22	.04	.26	.21	.14	.08	.58
3	.34	.12	.07	.23	.07	.05	.19	.07	.20	.03	.66

Effect of Music Exposure Task on INMI and Music Memory

On average, probability of experiencing a loop as INMI decreased across 1-week delay period (Exp. 1-3) while accuracy of a music memory increased (Exp. 1 and 2).



Directing attention away from music during exposure had no effect on loop memory accuracy or probability of experiencing a loop as INMI (Exp. 1 and 2).
Directing attention AND sensorimotor engagement away from music decreased the accuracy of loop memory and probability of experiencing a loop as INMI (Exp. 3).

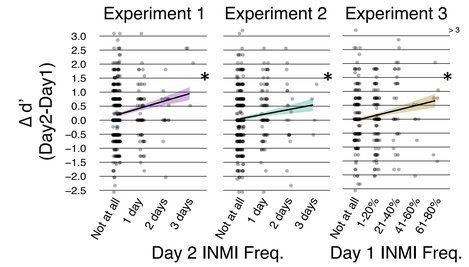
Results Cont'd.

Effect of INMI on Music Memory

Measures of loop-level memory change bootstrapped effect sizes and 95% CI

More frequent INMI episodes predicted more accurate loop memory (Exp. 1-3).

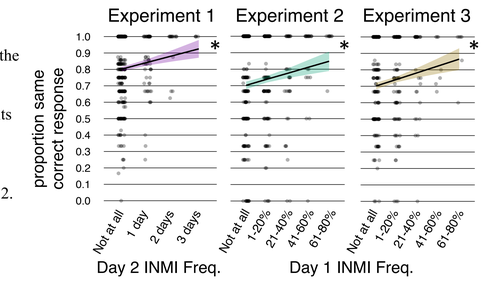
Exp.	dep. ind.	MSIR d' Day 2 – MSIR d' Day 1 (Δd')		
		Day 1 d'	Day 1 INMI freq.	Day 2 INMI freq.
1	Effect Size	-0.656 [-0.748, -0.562]	0.042 [-0.051, 0.134]	0.256 [0.096, 0.411]
2		-0.679 [-0.781, -0.577]	0.045 [-0.052, 0.145]	0.165 [0.003, 0.323]
3		-0.6 [-0.722, -0.485]	0.175 [0.031, 0.311]	0.068 [-0.137, 0.268]



More frequent INMI episodes predicted better maintenance of correct information (Exp. 1-3).

Exp.	dep. ind.	Proportion Same Correct Response (PSCR)		
		Day 1 d'	Day 1 INMI freq.	Day 2 INMI freq.
1	Effect Size	0.022 [0.001, 0.044]	0.015 [-0.005, 0.036]	0.041 [0.004, 0.077]
2		0.015 [-0.019, 0.048]	0.037 [0.003, 0.068]	0.035 [-0.017, 0.086]
3		0.049 [0.018, 0.082]	0.041 [0.003, 0.079]	0.001 [-0.052, 0.051]

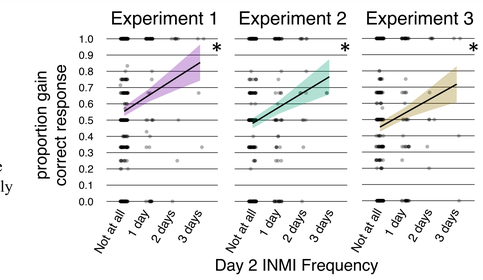
for a given loop, the proportion of correct Day 1 responses (i.e., hits and correct rejections) that were answered correctly on Day 2.



More frequent INMI episodes predicted more updating of incorrect information (Exp. 1-3).

Exp.	dep. ind.	Proportion Gain Correct Response (PGCR)		
		Day 1 d'	Day 1 INMI freq.	Day 2 INMI freq.
1	Effect Size	0.039 [-0.012, 0.089]	0.0 [-0.043, 0.042]	0.101 [0.03, 0.181]
2		0.005 [-0.048, 0.059]	-0.027 [-0.076, 0.018]	0.095 [0.019, 0.172]
3		0.04 [-0.014, 0.094]	-0.009 [-0.069, 0.05]	0.089 [0.008, 0.168]

For a given loop, proportion of incorrect Day 1 responses (i.e., misses and false alarms) that were answered correctly on Day 2.



Conclusions

INMI is a memory phenomenon: the spontaneous replay of music memories

A. Stronger encoding of a musical sequence leads to increased INMI frequency

B. More frequent INMI leads to greater improvements in musical sequence memory

- Improvements (Δd') a function of two INMI effects on memory:
  INMI during the experiment (Day 1) tends to protect against forgetting while
  INMI after the experiment (Day 2) improves poorly encoded memories