EXPERIMENT REPORT | 23–25 OCTOBER 2026

INK SPIRAL

渦巻銀河

Solo agent vs. agent team: an empirical study of AI-produced anime lyric music videos

Rezephyr - Lost Galaxy (feat. Hatsune Miku)

RESEARCH BY

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WITH

Yiyi, the agent & Yiyi, the cat



渦

Research: Ibn Ahmad ar-Raqmi, https://ar-raqmi.net

Lead agent: Yiyi | 24 sub-Yiyi runs

Claude Opus 5.5, max effort | Hermes Agent

Usage: runtime state DB | prices: Anthropic list, 25 Oct 2026

Private research document. Artworks © their artists (App. D).

Abstract 要旨

We report a three-phase field experiment in which a large-language-model agent, *Yiyi* (Claude Opus 5.5 at maximum reasoning effort, running in Hermes Agent), produced anime-style lyric music videos (MVs) for the artist Rezephyr. In **P1** it worked alone (*Like a Prism*). In **P2** and **P3** it led a team of sub-agents ("sub-Yiyis"): five storyboards, then a 3:41 strictly black-and-white manga MV in the INK SPIRAL style for **Rezephyr - Lost Galaxy (feat. Hatsune Miku)**. Token usage for the lead and all 24 sub-agent runs was read from the runtime's state database and priced at Anthropic list prices.

The experiment consumed **266.82 M tokens**, equivalent to **$237.18**; 90.9 % of the tokens were cheap cache reads. Against the solo MV, the team MV:

- locks frame changes to the drums **1.58–2.60× harder** (kick ×7.43 vs ×2.86 above random), measured with the same audit on both videos;
- is strictly monochrome: 0 of 241 sampled frames contain any colour;
- costs 2.75× more per finished minute and took 3.42× the wall-clock time, mostly spent waiting for usage-window resets.

The improvement came mainly from *pre-production*: craft research, a written doctrine, storyboards and data contracts. Sub-agents are what made that pipeline fit inside context and quota limits.

$237.18
API-list-price equivalent of all 266.82 M tokens

×7.43
team kick lock (solo ×2.86)

0 / 241
sampled frames with colour (strict B/W check)

97 shots
97-shot plan, 11 lettering treatments, 5300 frames

24 runs
sub-Yiyis: 14 completed, 5 paused, 5 failed

7.80 h
P3 time spent waiting for the 5-hour quota window

Key findings

1. **Craft improved where the doctrine targeted it.**
   - Stepped timing and hit-locked impacts raised the drum-sync ratios on every instrument (Fig. 10).
   - The hi-hat went from no real lock (solo peak at lag $+6$) to a lock on the hit frame.
   - Ten hand-built lettering treatments replaced default tweens.
2. **Cost is driven by context, not by headcount or duration.**
   - Per run, neither duration ($r = 0.20$) nor call count ($R^2 = 0.07$) predicts cost.
   - 62 % of the lead's own spend was cache *writes*: the lead re-cached its context after every idle wait.
3. **The binding constraint is the subscription quota.**
   - One 5-hour window $\approx$ 13.2 points of the weekly allowance.
   - The two team phases used $\approx$ 93 points of a week.
   - Wall-clock time was dominated by quota waits (Fig. 17).
4. **Verification had to come from tools, not reports.** Every defect found in P3 was caught by a script or by the lead re-checking:
   - a stale engine copy in the skills repo;
   - an ffmpeg-8 flag change that broke the QA script;
   - a cost model that violated an exact bound.

Contents 目次

1 Introduction and research questions 3

2 Materials and setup 3

3 Methods 4

4 Results I: the song 5

5 Results II: the music video 5

6 Results III: rhythm lock and solo vs team 11

7 Results IV: pre-production and research 11

8 Results V: time, tokens and cost 12

9 Discussion 15

10 Reuse: the anime-mv-skills repository 16

About this research 16

A Data provenance 17

B Every sub-Yiyi run 17

C Aligned lyrics 18

D Credits, sources and licences 18

1 Introduction and research questions 序

The artist's critique of the solo MV (P1) was specific:

- the typography was generic and not dynamic;
- motion was "too smooth", with default eases and fades;
- there was no frame-level glitching, although the reference MVs it studied all use dynamic custom lettering.

The follow-up phases tested whether a lead agent with sub-agents, given more research and more assets, could close that gap, and at what price. We ask:

RQ1 Quality. Does the team-made MV measurably improve rhythm-locked motion, lettering and style compliance over the solo MV?

RQ2 Cost. What does each approach consume in tokens, list-price dollars, wall-clock time and plan quota?

RQ3 Mechanism. Which inputs (research, assets, storyboards, contracts, parallelism) account for the difference?

Design. The units are three production phases inside one lead session:

- **P1**, solo: *Like a Prism*, 211.97 s, 175.09 BPM;
- **P2**, team: five storyboards for *Lost Galaxy*;
- **P3**, team: the INK SPIRAL MV plus a portable skills repository.

This is an observational comparison, not a randomised trial; Section 9 discusses the confounders.

2 Materials and setup 素材

Table 1 The two songs, as measured by the same analysis pipeline.

	P1 solo: Like a Prism	P3 team: Lost Galaxy
Duration	211.97 s	220.81 s
Tempo	175.09 BPM (linear fit over steady beats)	150 BPM, grid refit on 418 kick/snare hits
Key	A♭ major	C major
Drums (ADTOF)	kick 311, snare 338, hi-hat 867	kick 200, snare 218, hi-hat 275
Lyrics	36 lines, 137 words (romaji + English)	23 lines, 73 words (20 known)
Word-timing error	210 ms median (random 309 ms)	40 ms median (random 96 ms)
Vocal	male + female vocaloid	Hatsune Miku (vocaloid)

Agents. Lead and every sub-agent ran `claude-opus-5-5` through Anthropic's API on a subscription plan, at reasoning effort *max*. All 24 child sessions in the state database record that model and effort; nothing was routed to a cheaper model.

Hardware. One Linux workstation: 6 CPU cores, 23 GB RAM, NVIDIA GTX 1060 6 GB (CUDA sm_61). It was shared by up to six agents. Memory-capped scopes (`heavy.sh`) and a GPU lock (`gpu.sh`) prevented out-of-memory kills.

Toolchain.

- **Audio:** Demucs stems, Beat This! beats, ADTOF drums, faster-whisper large-v3, torchaudio MMS forced alignment, torchcrepe F0.
- **Rendering:** PixiJS/GLSL in headless Chromium for P1; a Python skia/numpy ink engine for P3; FFmpeg for encoding.

- **Report:** matplotlib and LuaLaTeX.

Links are in Appendix D.

3 Methods 方法

3.1 Production pipeline

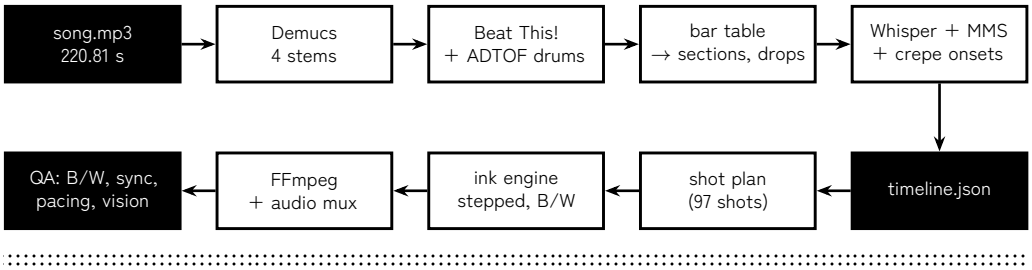


Figure 1 P3 pipeline. Solid boxes are the contracts and the gate: **`timeline.json`** is the only interface between the audio analysis and the renderer.

3.2 Team protocol

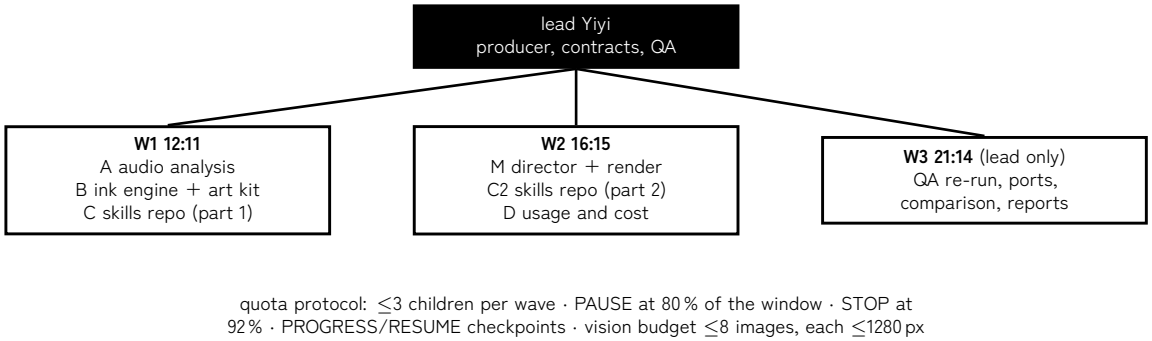


Figure 2 P3 organisation. Every worker owned a separate set of files and returned a JSON result; the lead re-verified each result with scripts (smoke tests, contract checker, B/W check, sync audit) before accepting it.

3.3 Measurements

Tokens and cost. The Hermes state database (`~/.hermes/state.db`) stores provider-reported input T_{in}, output T_{out}, cache-write T_{cw} and cache-read T_{cr} tokens per session. Child sessions link to the lead through `parent_session_id`. Cost at list price is

$$C = \sum_{s} \left(4\,T^{s}_{\text{in}} + 20\,T^{s}_{\text{out}} + 5\,T^{s}_{\text{cw}} + 0.2\,T^{s}_{\text{cr}}\right) \times 10^{-6}\ \text{USD},$$

using Opus 5.5 rates checked on 25 Oct 2026. Cache writes are priced at the 5-minute TTL that Hermes is configured with.

Attributing the lead's cost to phases. The database keeps the lead only as a running total, so its split across phases must be estimated. We use two estimators:

- *transcript replay*: `usage.py` replays timestamps and message sizes, then scales to the exact total;
- *snapshot-anchored*: the 16:34 snapshot taken by sub-Yiyi D, plus all growth after it, assigned to P3.

An *exact* bound decides between them. All lead spend after 16:34 was P3 work, which gives $C_{\text{P3}} \geq$

$C_{\mathrm{P3}}^{\mathrm{sub}} + \Delta C_{16:34\to\mathrm{end}}^{\mathrm{lead}} = \$50.57$. The replay estimate (\$41.25) violates this bound, so we report the snapshot-anchored figures as primary.

Drum sync audit. Let $\Delta(t)$ be the mean absolute luminance change between consecutive frames sampled at 30 fps. For hits H_k of instrument k and random times U:

$$r_k(\ell) = \frac{\mathrm{mean}_{h\in H_k}\,\Delta(h+\ell)}{\mathrm{mean}_{u\in U}\,\Delta(u)}, \qquad \ell \in \{-4,\dots,6\}\ \text{frames}.$$

The same script ran on both masters. The solo audit was re-run to recover its full lag profile, and it reproduced the stored peaks exactly.

Style compliance. A frame is monochrome iff $U = V = 128$ in YUV and $R = G = B$ after decoding. We checked 241 frames, one every 22 frames.

Lyric timing. The error is the median distance from each aligned word start to the nearest vocal onset, compared with the same statistic for random times.

4 Results I: the song 解析

Table 2 Section map (bars are 1.6 s at 150 BPM).

Section	Bars	Start	End	Length s	Energy
INTRO	1-4	0.00	6.45	6.5	0.20
VERSE 1	5-20	6.45	32.05	25.6	0.25
BREAK 1	21-28	32.05	44.85	12.8	0.56
CHORUS 1	29-36	44.85	57.65	12.8	0.57
BUILD 1	37-44	57.65	70.45	12.8	0.71
DROP 1	45-59	70.45	94.45	24.0	0.66
VERSE 2	60-68	94.45	108.85	14.4	0.40
CHORUS 2	69-76	108.85	121.65	12.8	0.69
BUILD 2	77-84	121.65	134.45	12.8	0.73
DROP 2	85-99	134.45	158.45	24.0	0.65
BREAK 2	100-104	158.45	166.45	8.0	0.32
BRIDGE	105-112	166.45	179.25	12.8	0.17
DROP 3	113-127	179.25	203.25	24.0	0.75
OUTRO	128-138	203.25	220.81	17.6	0.29

5 Results II: the music video 映像

Table 4 Deliverable QA (`qa/qa_final.json`).

Master	1920×1080, 24 fps, H.264 crf 17 + AAC 320k, 5300 frames rendered in 669.7 s (7.91 fps)
Duration	video vs audio differ by 21 ms (under one frame)
Monochrome	0 of 241 frames with chroma or $R \neq G \neq B$; median screentone area 9.0 %
Credits	title and end card read exactly *Rezephyr - Lost Galaxy (feat. Hatsune Miku)*
Share copy	10.7 Mbit/s, end card held 6 s longer for readability

6 Results III: rhythm lock and solo vs team 同期

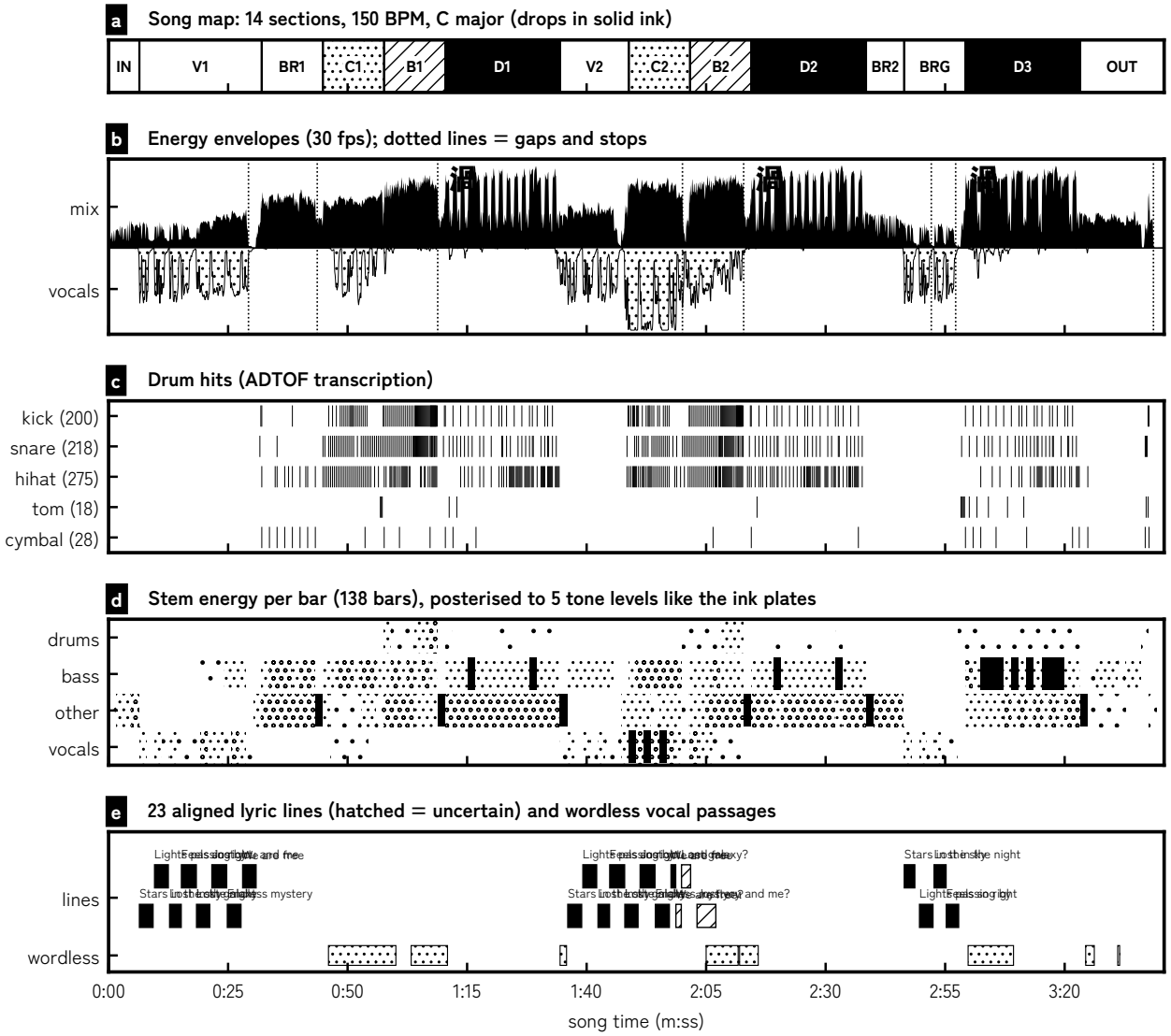


Figure 3 Lost Galaxy decomposed. Three drops (solid ink) land on downbeats at 1:10.45, 2:14.45 and 2:59.25. Drops 1–2 follow a snare build that steps from quarter notes to 8ths to 16ths, then a one-bar gap; drop 3 follows a full stop and a tom fill. The drops are half-time (kick on 1, clap on 3), which is why their mix energy is lower than the builds' (panel d).

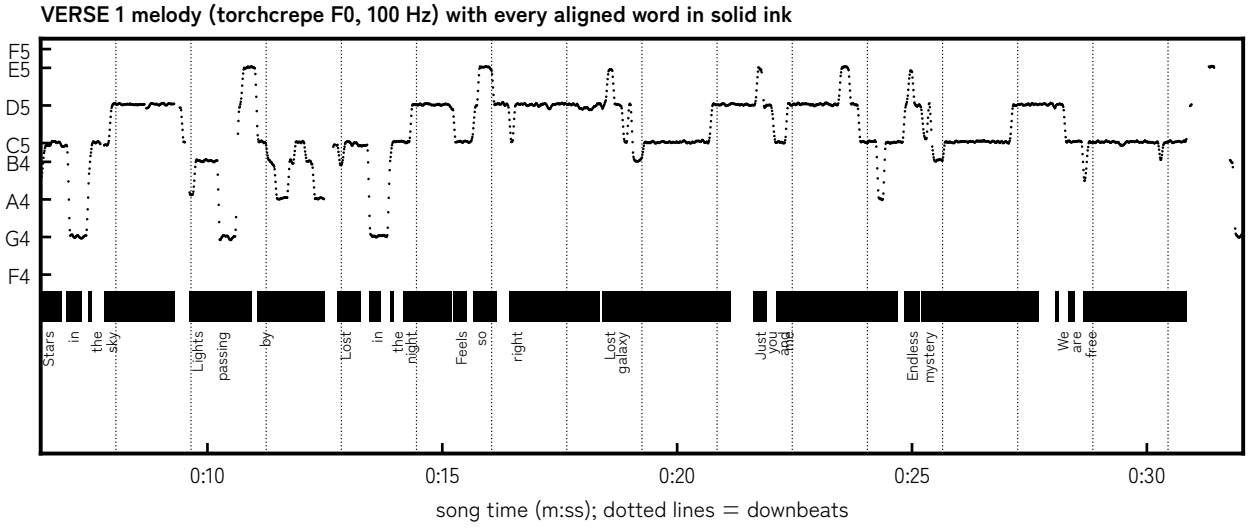


Figure 4 Verse 1 melody against the aligned words. Repeats of the verse land at exact bar offsets (56 and 100 bars) to within 0.1 s, which is why their timing is trusted even where MMS confidence is low.



Figure 5 The INK SPIRAL MV at 0:29: “WE ARE FREE” carved white out of ink, with 自由 in kanji stroke order. Every frame is pure black, white and screentone.

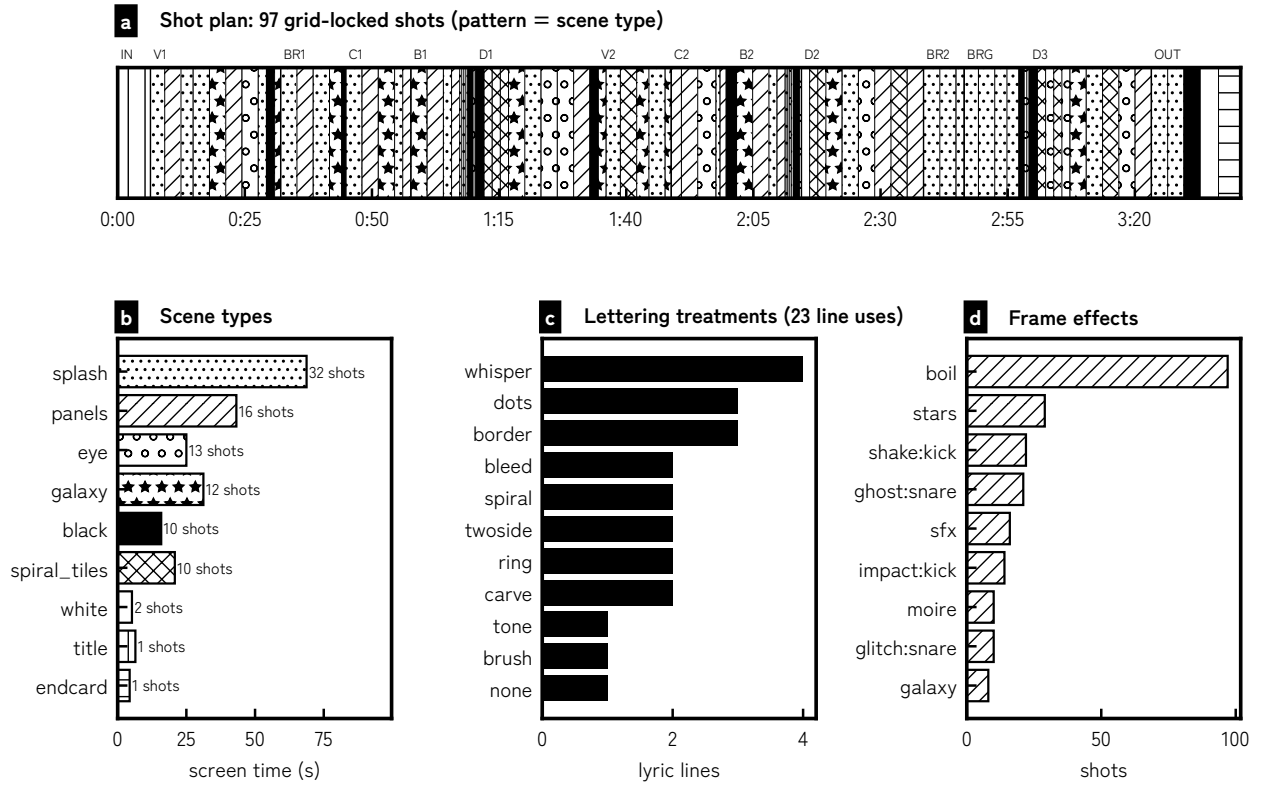


Figure 6 The 97-shot plan, produced by a generator from **`timeline.json`**. Splash pages and panel grids carry the verses; eye close-ups and spiral tiles carry the drops. Each verse line has its own lettering treatment on its first appearance, and repeats vary it. SFX used: ズズズ (×12), ゴゴゴ (×4), ドクン (×3), 渦 (×3).

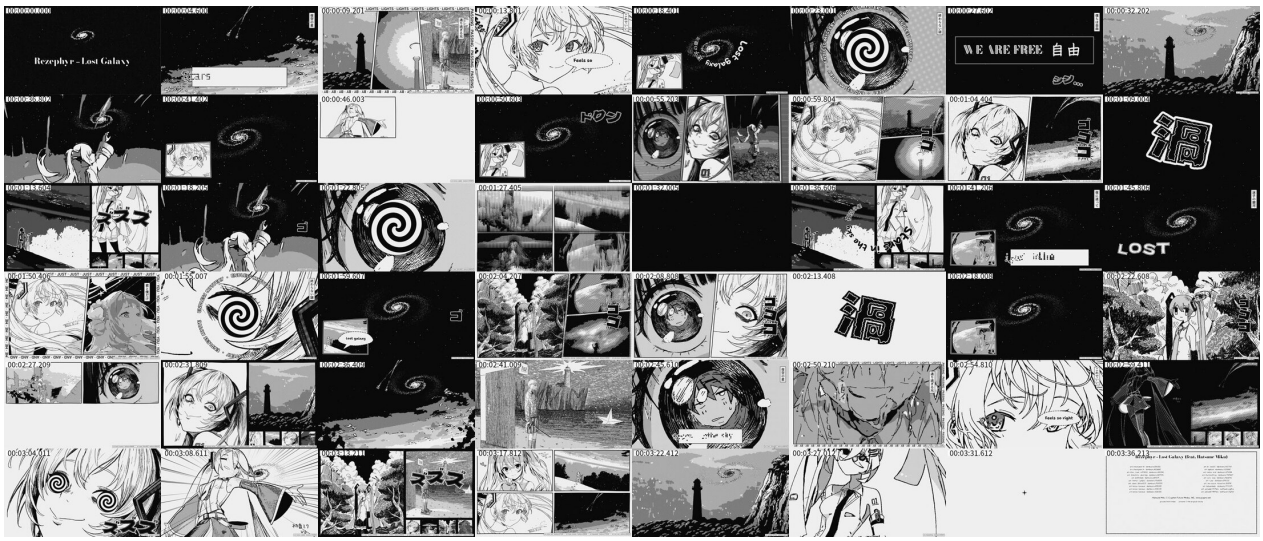


Figure 7 Pacing sheet: 48 frames at equal time steps across the whole MV. The black frames are the scripted one-bar gaps held as **シン…**, not dropouts.



Figure 8 Lyric legibility: “Stars in the sky” (dot treatment), “Lost galaxy” (spiral-set), “WE ARE FREE 自由” (carved), and the end card with the title and 20 art credits.



Figure 9 The art kit: 20 sourced artworks re-inked into line, solid black and discrete tone plates. Credits are in Appendix D.

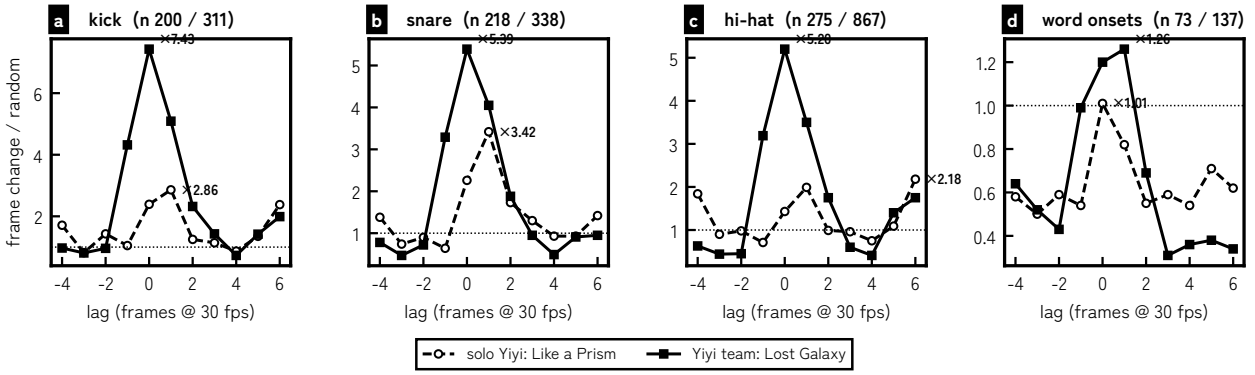


Figure 10 Drum-sync lag profiles from the same audit on both MVs. The team MV peaks on the hit frame (lag 0) for kick, snare and hi-hat. The solo MV peaks one frame late, and its hi-hat curve has no real peak. Word onsets barely move the whole-frame metric in either video, because a word changes only a small part of the frame.



Figure 11 Same four moments (verse, chorus, first drop, last drop). Top: solo Like a Prism. Bottom: team Lost Galaxy. The colour frames are shown in greyscale to match the house style.

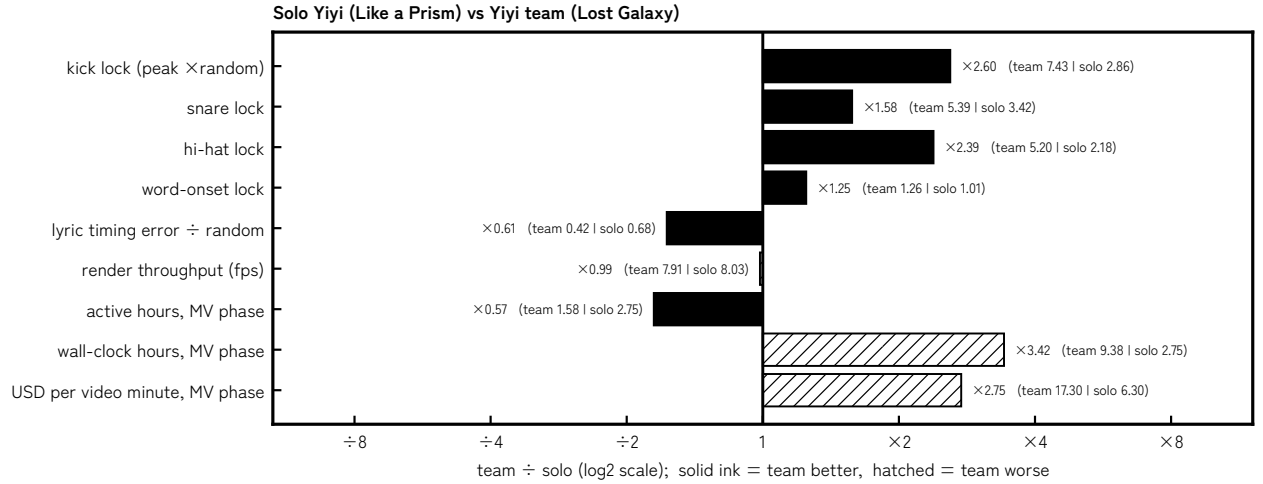


Figure 12 Team ÷ solo on nine metrics (log scale). Solid bars are where the team is better. The quality metrics improve; time and money get worse.

Reading Fig. 12 carefully

- **The ratios compare different songs.** The lyric-timing gain (0.61×) mixes in an easier song (English, 150 BPM) against a harder one (romaji/English, 175 BPM).
- **Hits co-occur.** Hi-hats fall on kick and snare positions, so the instrument ratios are not independent.
- **The cost ratio is conservative.** It counts only the MV phase. Including the P2 storyboards, the team spent roughly 7.5–10× the solo budget.

7 Results IV: pre-production and research

絵コンテ

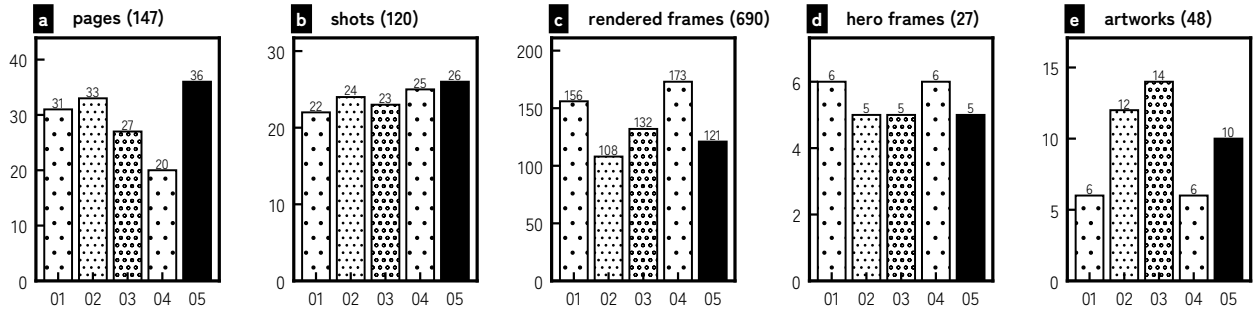


Figure 13 P2 output: five storyboards forced ≥80 % apart by a 15-axis difference matrix. Totals: 147 pages, 120 shots, 690 rendered frames, 27 hero frames and 48 ledger entries. All boards passed the 21-check contract.



Figure 14 One hero frame per style (01 FEED CRASH, 02 COMET CINEMA, 03 AMANOGAWA, 04 VHS 1989, 05 INK SPIRAL). Shown in greyscale; the colour originals are in the storyboard repository.

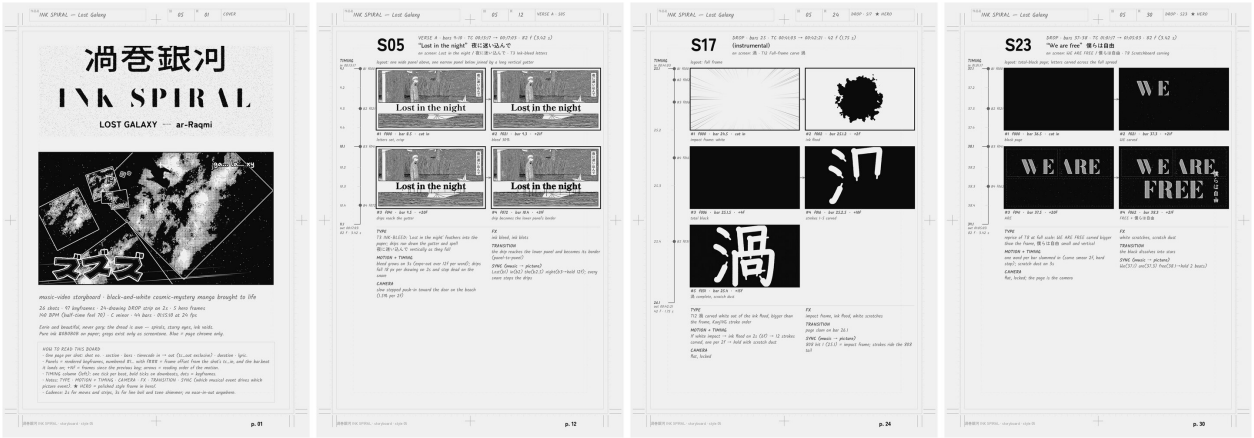


Figure 15 INK SPIRAL storyboard pages 1, 12, 24 and 30: the board the MV was built from.

Rezephyr - Lost Galaxy (feat. Hatsune Miku)

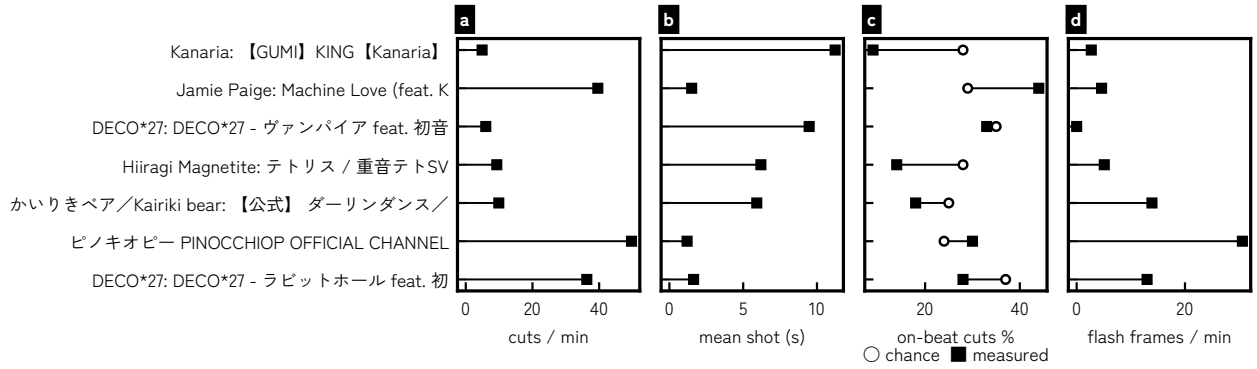


Figure 16 The seven reference MVs measured in P1. They cut rarely, at 1–10 cuts per minute, and cuts land on beats about as often as chance. That evidence moved the team's grammar away from cutting on every hit: layouts change on phrases, and per-beat energy goes into impacts.

Reference MV	Channel	Views M	BPM	Cuts/min	Shot s	On-beat %	Link
【GUMI】KING【Kanaria】	Kanaria	107.4	167	4.9	11.2	9 (chance 28)	https://www.youtube.com/watch?v=cm-l2h6GB8Q
Machine Love (feat. Kasane Teto)	Jamie Paige / JamieP	32.7	176	39.6	1.5	44 (chance 29)	https://www.youtube.com/watch?v=sqK-jh4TDXo
DECO*27 - ヴァンパイア feat. 初音ミク	DECO*27	100.2	167	6.0	9.5	33 (chance 35)	https://www.youtube.com/watch?v=e1xCOsgWG0M
テトリス / 重音テトSV	Hiiragi Magnetite	136.6	167	9.3	6.2	14 (chance 28)	https://www.youtube.com/watch?v=Soy4jGPHr3g
【公式】ダーリンダンス／かいりきベア feat.初音ミク	かいりきベア／Kairiki bear	50.0	150	9.9	5.9	18 (chance 25)	https://www.youtube.com/watch?v=Rkrm5foi188
ピノキオピー - 神っぽいな feat. 初音ミク / God-ish	ピノキオピー PINOCCHIOP OFFICIAL CHANNEL	94.3	143	49.7	1.2	30 (chance 24)	https://www.youtube.com/watch?v=EHBFKhLUVig
DECO*27 - ラビットホール feat. 初音ミク	DECO*27	127.5	176	36.3	1.6	28 (chance 37)	https://www.youtube.com/watch?v=eSW2LVbPThw

8 Results V: time, tokens and cost 費用

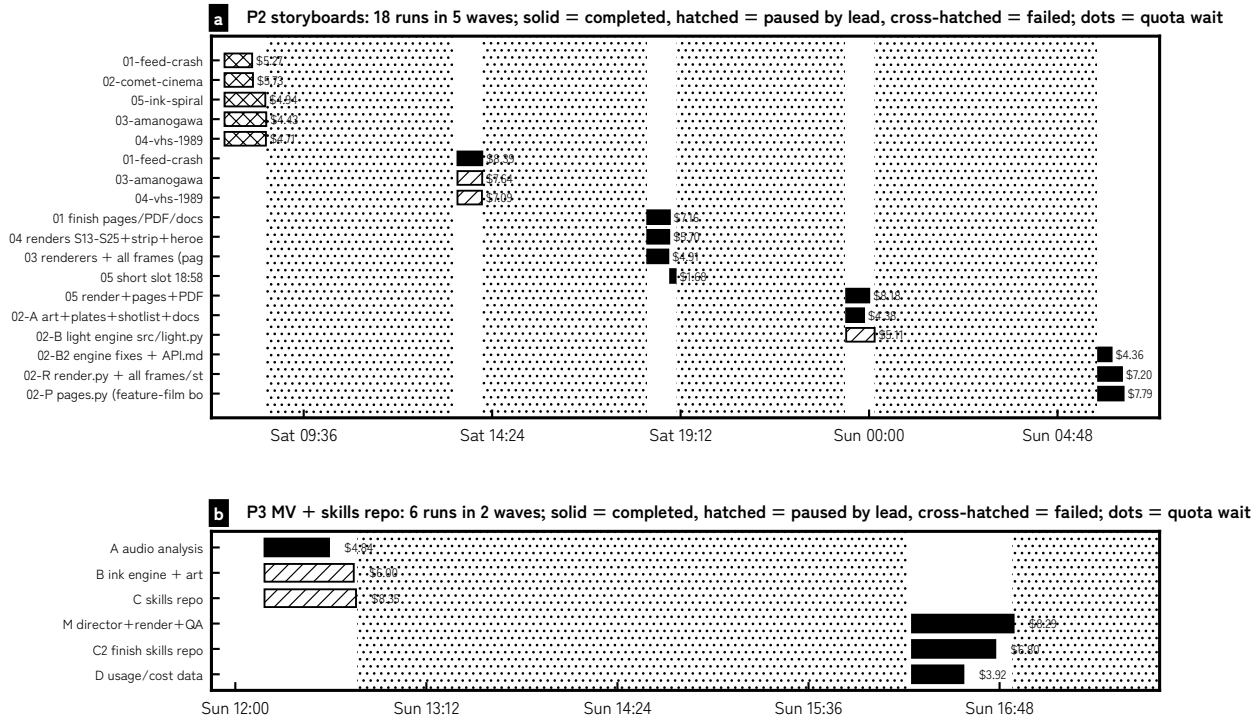


Figure 17 All 24 sub-Yiyi runs on the clock. The dotted bands are quota waits: P2 lost 18.86 h of 23.41 h to them, and P3 7.80 h of 9.38 h. The first P2 wave (five parallel children) exhausted a 5-hour window in about 24 minutes, and those runs failed on rate limits and an oversized image.

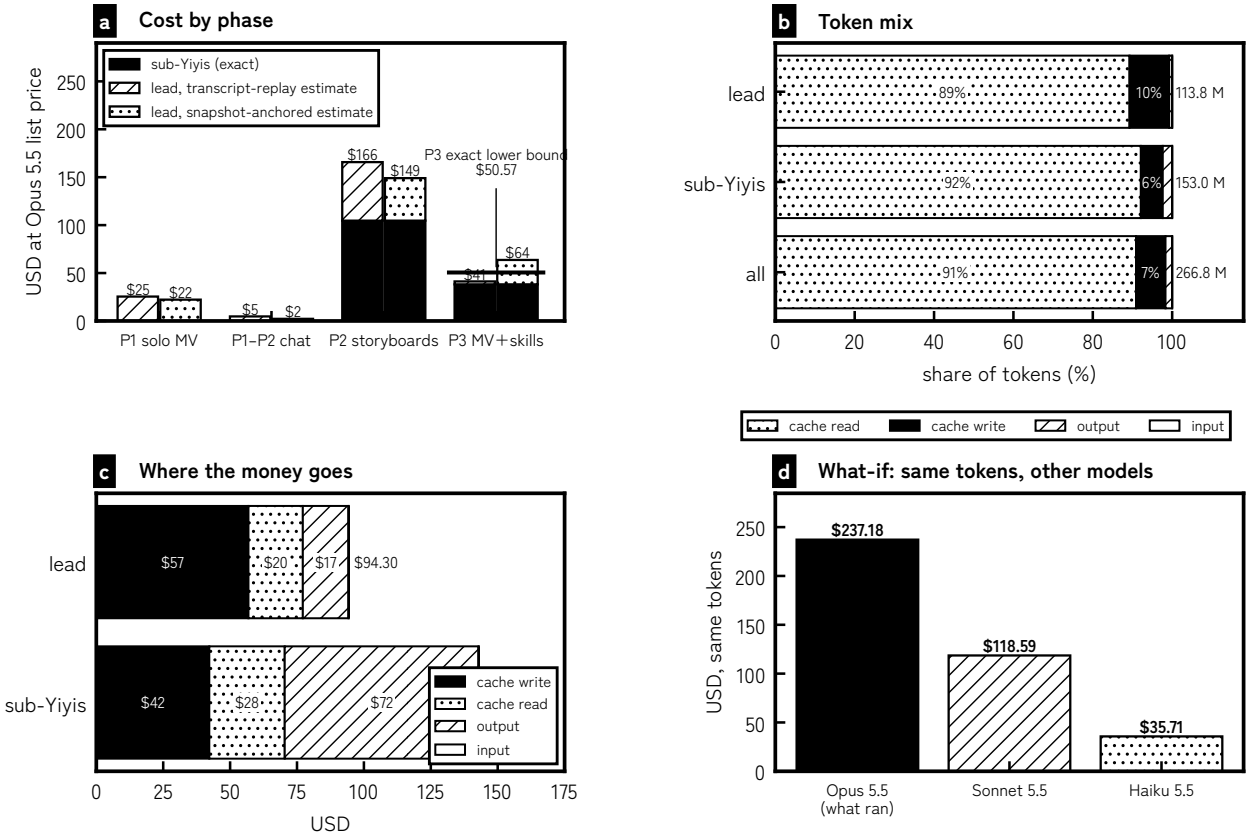


Figure 18 (a) Cost by phase under both estimators, with the exact P3 lower bound. (b) Token mix. (c) Where the dollars go: cache writes dominate the lead ($56.02 of $90.86 in its main loop, ≈31.9k tokens per call). (d) The same tokens priced on other models: Sonnet 5.5 $118.59, Haiku 5.5 $35.71.

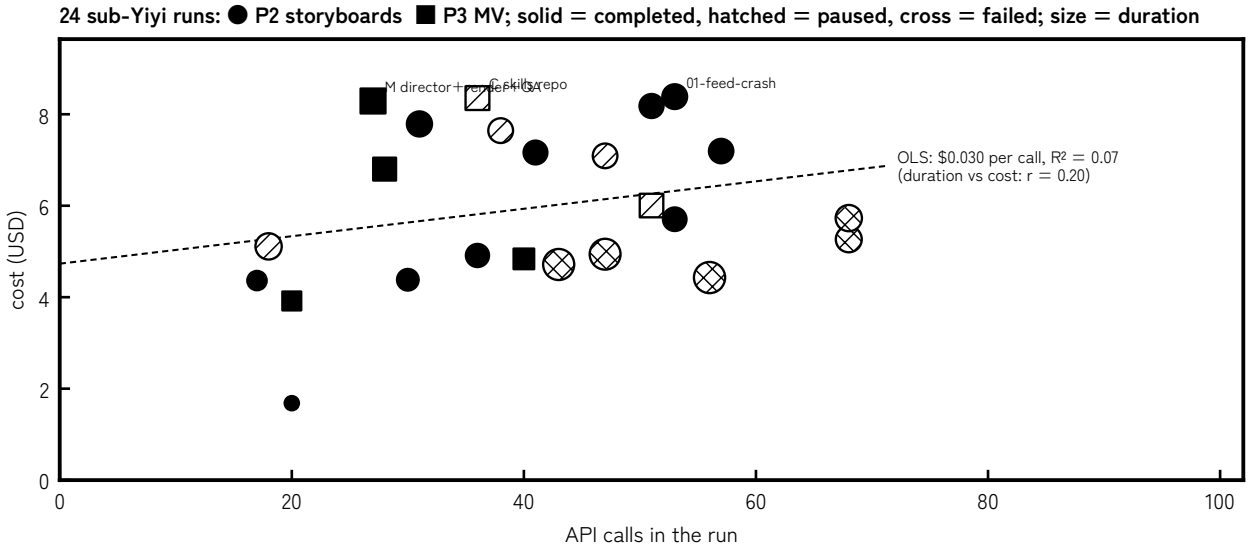


Figure 19 Per-run cost against API calls. The fit is weak ($R^2 = 0.07$; duration vs cost $r = 0.20$). Cost per run is set by how much context each call carries, not by how long the run lasts.

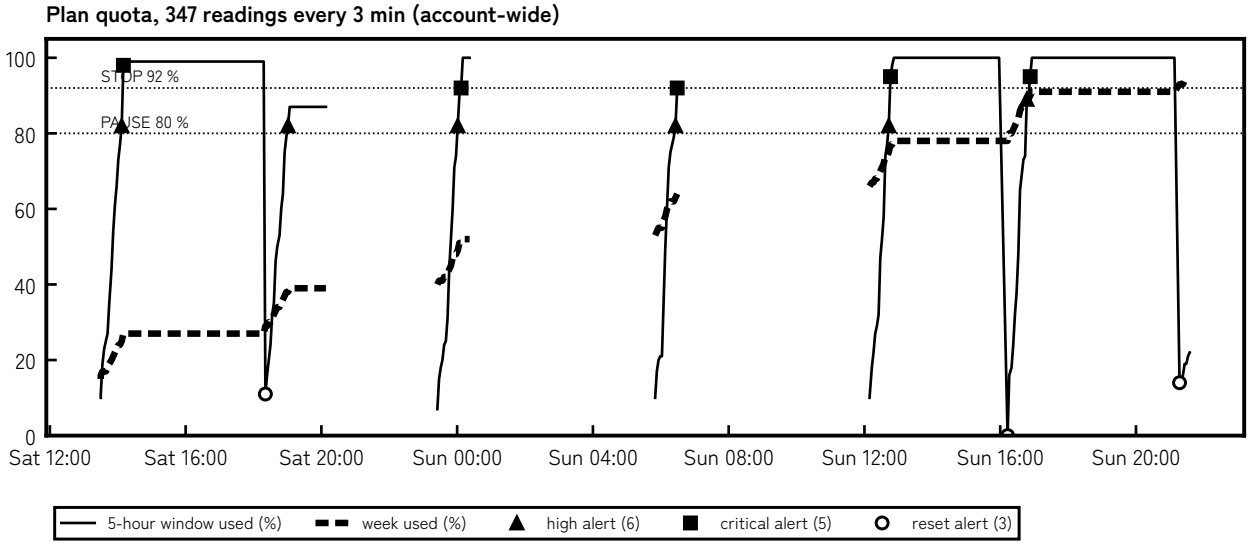


Figure 20 The subscription view: 347 readings of the 5-hour window and the weekly allowance. Each sawtooth is a window filling up and resetting. The week reached 94 % by the end of P3.

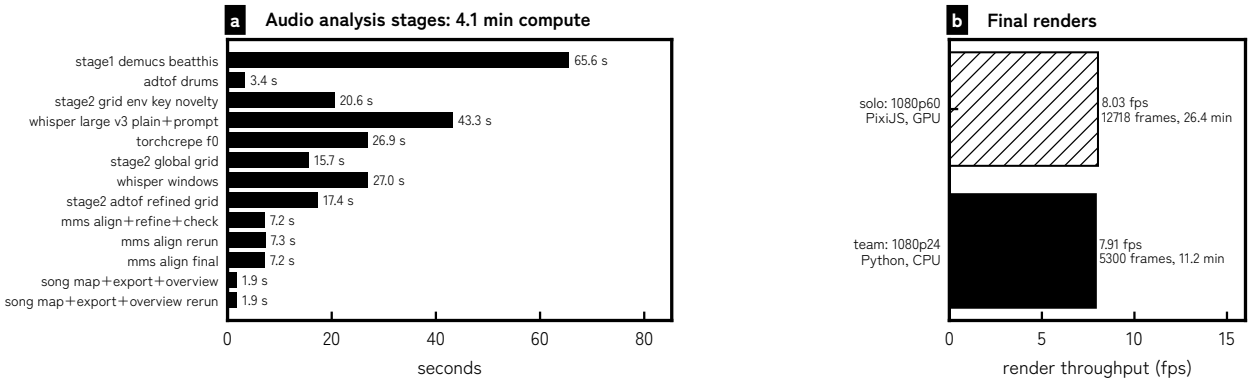


Figure 21 Compute is cheap next to agent time. The whole audio analysis took minutes. Renders ran at about 8 fps in both pipelines: GPU WebGL for P1, CPU Python for P3.

9 Discussion 考察

9.1 What research and assets bought (RQ3)

1. **Research changed the target.** P1 studied how reference MVs *cut*. P2 studied the *craft* the critique was about: 文字PV composition, 作字 lettering, kinetic typography. It wrote that into one doctrine of stepped timing, no fades, impact frames and a glitch vocabulary per style. Fig. 10 is the measurable trace of that doctrine.
2. **Storyboards made directing cheap.** The board had already settled the motion grammar, the drop concept and the SFX vocabulary. One sub-Yiyi turned it into a 97-shot plan and a full render in a single 38-minute run.
3. **More assets moved variety from effects to content.** With 20 inked artworks, shots change by framing (eyes, hands, back view, town, sea), and effects stay sparse. P1, with three source images, had to fill 3.5 minutes with shader motion.
4. **Contracts made quality checkable.** The timeline schema, the board checker, the smoke tests, the B/W check and the sync audit let the lead verify without trusting self-reports.

9.2 Threats to validity

The comparison is not controlled:

- the songs, styles and languages differ;
- the team had the critique of P1 in its brief;
- the team spent roughly 7.5–10× the budget.

A solo agent given the same research and storyboards over several sessions might close part of the gap. Some measurements have limits of their own:

- quota percentages are account-wide (other sessions ran in parallel), so they are upper bounds;
- the lead's phase split is an estimate, bounded where exact data allow;
- the vision critiques are qualitative, and no human has yet watched the MV with sound.

9.3 Known weaknesses of the MV

- It is a motion comic, not character animation.
- The spiral and the 渦 slam open all three drops.
- Miku's model changes between shots, because the art comes from ten artists.
- Inking photo-like sources goes muddy.
- The verse-1 dot lettering is noisy.
- Lines L17–L19 (118.7–125 s) are uncertain transcriptions, shown subdued or wordless.

9.4 Lessons

1. Pre-production beats headcount: research the craft, write a doctrine, storyboard, then build.
2. Waves of at most three, separate files per worker, written contracts, and checkpoints that survive a pause.
3. Budget the lead: keep its context small and wake it rarely, because idle waits turn into cache writes.
4. Budget against the week, not the window.
5. Verify with probes that can fail. Expect toolchain drift (ffmpeg 8 removed `-vsync`).

10 Reuse: the anime-mv-skills repository 再利用

P3 packaged the procedures into `anime-mv-skills`: seven agent skills, an offline smoke test (89 passed, 0 failed, 1 skipped), an installer and an MIT licence. It is not tied to INK SPIRAL: Style-independent skills: `mv-audio-analysis`, `kinetic-typography`, `mv-qa`, `agent-team-orchestration`. To install: `./install.sh --target ~/.hermes/skills` (or `~/.claude/skills`), then `bash tests/smoke.sh`. For other or smaller models, the repository's rule is to let the validators define "done": give one milestone per session and require exact commands and a JSON result.

Table 8 Customising the style: what changes at each level.

Level	What changes	Code?
1. New project, same look	song, art, title, captions, ink presets (`ink_project.json`); shot table: scenes, lettering per line, which hits get impacts	no
2. Variant of the look	fonts (`lib/common.py` roles), SFX words, tuned treatments	small edits
3. New style family	storyboard it (`mv-storyboards`, style brief and difference matrix); build on the colour GLSL template (`lyric-mv-gpu-render`) or add scene types to the ink engine	yes

About this research 猫

Researcher

Ibn Ahmad ar-Raqmi designed and ran this experiment: he wrote the briefs and the critique, judged every output, and supplied the songs (released as Rezephyr).

Website: https://ar-raqmi.net

Yiyi, the agent

The lead agent that produced the MVs, storyboards, skills repository and this report: Claude Opus 5.5 running in Hermes Agent, directing 24 sub-agent runs ("sub-Yiyis").

Yiyi, the cat

The original Yiyi, and the agent's namesake: a fluffy white longhair with an orange-and-dark head patch. As the experiment's champion napper, she supervised from the keyboard. No quota was harmed by her naps.



Yiyi the cat, on duty at the render workstation. Photo: Ibn Ahmad ar-Raqmi.

A Data provenance 出典

Data	Produced by	Used in
`report/usage.json`	sub-Yiyi D, `usage.py` over `state.db` (read-only)	Tab. 6, Fig. 17, 18, 19, App. B
`qa/usage_monitor.log`	quota monitor, every 3 min	Fig. 20
`engine/data/timeline.json`	sub-Yiyi A, audio pipeline	Fig. 3, 4, App. C
`analysis/bars.json`, `runtimes.tsv`	sub-Yiyi A	Fig. 3, 21
`engine/data/shots_lost_galaxy.json`	sub-Yiyi M, plan generator	Fig. 6
`qa/sync_audit*.log`	`sync_audit.py`, both MVs	Fig. 10, 12
`qa/qa_final.json`	`qa_final.py`	Tab. 4
`research/reference_stats.json`	P1 reference study	Fig. 16
`*/credits.jsonl`	`art.py` ledgers	App. D

All numbers in this report are typeset from `gen/numbers.tex`, which `make_figures.py` writes from these files. The exception is the four alignment medians, which are copied from the check-alignment reports.

B Every sub-Yiyi run 全記録

#	Ph.	Wave	Sub-Yiyi run	Status	Start	Min	Calls	Mtok	CW Mtok	USD
1	P2	P2 w1 24 07:35	01-feed-crash	failed (image_too_large)	24 Oct 07:35	42.2	68	8.98	0.34	5.27
2	P2	P2 w1 24 07:35	02-comet-cinema	failed (image_too_large)	24 Oct 07:35	43.5	68	10.19	0.32	5.73
3	P2	P2 w1 24 07:35	05-ink-spiral	failed (rate_limit)	24 Oct 07:35	62.3	47	7.87	0.26	4.94
4	P2	P2 w1 24 07:35	03-amanogawa	failed (rate_limit)	24 Oct 07:35	63.8	56	8.05	0.22	4.43
5	P2	P2 w1 24 07:35	04-vhs-1989	failed (rate_limit)	24 Oct 07:35	63.2	43	6.46	0.28	4.71
6	P2	P2 w2 24 13:31	01-feed-crash	completed	24 Oct 13:31	37.9	53	9.96	0.40	8.39
7	P2	P2 w2 24 13:31	03-amanogawa	paused by lead	24 Oct 13:31	37.8	38	6.79	0.39	7.64
8	P2	P2 w2 24 13:31	04-vhs-1989	paused by lead	24 Oct 13:31	37.4	47	8.01	0.31	7.09
9	P2	P2 w3 24 18:21	01 finish pages/PDF/docs	completed	24 Oct 18:21	34.6	41	6.95	0.43	7.16
10	P2	P2 w3 24 18:21	04 renders S13-S25+strip+heroes (pages if budget)	completed	24 Oct 18:21	33.7	53	7.12	0.38	5.70
11	P2	P2 w3 24 18:21	03 renderers + all frames (pages if budget)	completed	24 Oct 18:21	32.3	36	5.24	0.22	4.91
12	P2	P2 w4 24 18:56	05 short slot 18:58	completed	24 Oct 18:56	8.4	20	1.41	0.09	1.68
13	P2	P2 w5 24 23:25	05 render+pages+PDF	completed	24 Oct 23:25	35.3	51	9.45	0.48	8.18
14	P2	P2 w5 24 23:25	02-A art+plates+shotlist+docs (PROGRESS_A.md)	completed	24 Oct 23:25	27.4	30	3.03	0.31	4.38
15	P2	P2 w5 24 23:25	02-B light engine src/light.py + lab/ (PROGRESS_B.md)	paused by lead	24 Oct 23:25	43.5	18	2.47	0.36	5.11
16	P2	P2 w6 25 05:50	02-B2 engine fixes + API.md	completed	25 Oct 05:50	20.7	17	2.30	0.26	4.36
17	P2	P2 w6 25 05:50	02-R render.py + all frames/strip/heroes + QA + runs pages.py + check_board	completed	25 Oct 05:50	36.5	57	10.48	0.37	7.20
18	P2	P2 w6 25 05:50	02-P pages.py (feature-film board, placeholder-tolerant) + CREDITS + REPORT	completed	25 Oct 05:50	39.0	31	6.19	0.54	7.79
19	P3	P3 w1 25 12:11	A audio analysis	completed	25 Oct 12:11	24.3	40	5.56	0.23	4.84
20	P3	P3 w1 25 12:11	B ink engine + art	paused by lead	25 Oct 12:11	33.6	51	7.36	0.25	6.00

#	Ph.	Wave	Sub-Yiyi run	Status	Start	Min	Calls	Mtok	CW Mtok	USD
21	P3	P3 w1 25 12:11	C skills repo	paused by lead	25 Oct 12:11	34.5	36	6.70	0.52	8.35
22	P3	P3 w2 25 16:15	M director+render+QA	completed	25 Oct 16:15	38.3	27	4.88	0.87	8.29
23	P3	P3 w2 25 16:15	C2 finish skills repo	completed	25 Oct 16:15	31.4	28	5.74	0.37	6.80
24	P3	P3 w2 25 16:15	D usage/cost data	completed	25 Oct 16:15	19.4	20	1.83	0.24	3.92

C Aligned lyrics 歌詞

ID	Section	Line	Start s	End s	Words	Conf.	Source
L01	VERSE 1	Stars in the sky	6.45	9.30	4	0.69	known verse
L02	VERSE 1	Lights passing by	9.62	12.49	3	0.61	known verse
L03	VERSE 1	Lost in the night	12.77	15.19	4	0.66	known verse
L04	VERSE 1	Feels so right	15.24	18.35	3	0.50	known verse
L05	VERSE 1	Lost galaxy	18.40	21.15	2	0.46	known verse
L06	VERSE 1	Just you and me	21.61	24.70	4	0.28	known verse
L07	VERSE 1	Endless mystery	24.84	27.69	2	0.49	known verse
L08	VERSE 1	We are free	28.05	30.85	3	0.36	known verse
L09	VERSE 2	Stars in the sky	96.06	98.96	4	0.47	known verse
L10	VERSE 2	Lights passing by	99.22	102.10	3	0.60	known verse
L11	VERSE 2	Lost in the night	102.39	104.79	4	0.59	known verse
L12	VERSE 2	Feels so right	104.84	107.95	3	0.41	known verse
L13	CHORUS 2	Lost galaxy	108.00	110.75	2	0.19	known verse
L14	CHORUS 2	Just you and me	111.20	114.30	4	0.31	known verse
L15	CHORUS 2	Endless mystery	114.39	117.31	2	0.28	known verse
L16	CHORUS 2	We are free	117.66	118.63	3	0.24	known verse
L17	CHORUS 2	We are free (?)	118.68	119.80	3	0.10	transcribed
L18	CHORUS 2	Lost galaxy (?)	119.85	121.75	2	0.13	transcribed
L19	BUILD 2	Just you and me (?)	123.10	127.03	4	0.09	transcribed
L20	BRIDGE	Stars in the sky	166.45	168.65	4	0.70	known verse
L21	BRIDGE	Lights passing by	169.64	172.45	3	0.58	known verse
L22	BRIDGE	Lost in the night	172.68	175.19	4	0.65	known verse
L23	BRIDGE	Feels so right	175.24	177.82	3	0.45	known verse

D Credits, sources and licences クレジット

D.1 Artworks

The table lists every third-party artwork used in the MV (MV) or in a storyboard (SB01–SB05), 58 works in total, each with its post page and its original source as recorded by `art.py`.

- The artworks remain © their artists.
- They appear in this report only as parts of storyboard pages, inked plates and MV frames, in a private, non-commercial research document.
- Hatsune Miku © Crypton Future Media, INC. https://www.piapro.net (piapro character licence).

#	Work	Artist	Post page / original source	Used in	Licence
1	danbooru:10230681 vocaloid / hatsune_miku	lughost	https://danbooru.donmai.us/posts/10230681 https://twitter.com/Lughostin/status/1962214146889421168	MV	© the artist (reference use only)
2	danbooru:11045595 vocaloid / hatsune_miku hatsune_miku_(vocaloid6)	inemuri_(jdq5e)	https://danbooru.donmai.us/posts/11045595 https://x.com/JDq5e/status/2037901700355465613	MV	© the artist (reference use only)
3	danbooru:11615427 vocaloid / hatsune_miku	rhymewithray	https://danbooru.donmai.us/posts/11615427 https://x.com/RhymeWithRay/status/2067342957464998202	MV	© the artist (reference use only)
4	danbooru:11750325 vocaloid / hatsune_miku	tatyaoekaki	https://danbooru.donmai.us/posts/11750325 https://i.pximg.net/img-original/img/2026/05/31/17/30/44/145434101_p3.jpg	MV	© the artist (reference use only)
5	danbooru:4380385 vocaloid / hatsune_miku	konya_karasue	https://danbooru.donmai.us/posts/4380385 https://i.pximg.net/img-original/img/2021/02/21/23/51/36/87951954_p2.jpg	MV	© the artist (reference use only)

#	Work	Artist	Post page / original source	Used in	Licence
6	danbooru:4380386 vocaloid / hatsune_miku	konya_karasue	https://danbooru.donmai.us/posts/4380386 https://i.pximg.net/img-original/img/2021/02/21/23/51/36/87951954_p3.jpg	MV	© the artist (reference use only)
7	danbooru:4380389 vocaloid / hatsune_miku	konya_karasue	https://danbooru.donmai.us/posts/4380389 https://i.pximg.net/img-original/img/2021/02/21/23/51/36/87951954_p5.jpg	MV	© the artist (reference use only)
8	danbooru:5065109 kono_subarashii_sekai_ni_shukufuku_wo! / megumin satou_kazuma	izawa_(bhive003)	https://danbooru.donmai.us/posts/5065109 https://twitter.com/bhive003/status/1483554738784575488	MV, SB05	© the artist (reference use only)
9	danbooru:5658318 original	rune_xiao	https://danbooru.donmai.us/posts/5658318 https://i.pximg.net/img-original/img/2022/09/08/02/30/34/101073335_p0.png	MV, SB05	© the artist (reference use only)
10	danbooru:6036892 vocaloid / ia_(vocaloid)	cheonyeon-hi	https://danbooru.donmai.us/posts/6036892 https://twitter.com/chohui94/status/1620358386109018117	MV, SB05	© the artist (reference use only)
11	danbooru:6227316 vocaloid / hatsune_miku	dokumitsu_akaringo	https://danbooru.donmai.us/posts/6227316 https://i.pximg.net/img-original/img/2021/03/23/14/56/34/88650298_p0.png	MV	© the artist (reference use only)
12	danbooru:6714284 vocaloid / hatsune_miku	metsu_end	https://danbooru.donmai.us/posts/6714284 https://i.pximg.net/img-original/img/2023/09/05/14/07/37/111442856_p0.png	MV	© the artist (reference use only)
13	danbooru:6872275 sousou_no_frieren / frieren	dotthebot	https://danbooru.donmai.us/posts/6872275 https://i.pximg.net/img-original/img/2023/11/08/06/27/04/113233185_p0.png	MV, SB05	© the artist (reference use only)
14	danbooru:6902252 genshin_impact / furina_(genshin_impact)	cheonyeon-hi	https://danbooru.donmai.us/posts/6902252 https://twitter.com/chohui94/status/1726895835458457912	MV, SB05	© the artist (reference use only)
15	danbooru:8261542 blue_archive / mika_(blue_archive)	dixo_(user_srff3835)	https://danbooru.donmai.us/posts/8261542 https://i.pximg.net/img-original/img/2024/10/07/11/39/56/123114531_p0.jpg	MV, SB05	© the artist (reference use only)
16	danbooru:8743322 original	ryaw	https://danbooru.donmai.us/posts/8743322 https://twitter.com/ryaw_2523/status/1833140448237593048	MV, SB05	© the artist (reference use only)
17	danbooru:9337754 vocaloid / hatsune_miku	le_(szs0k)	https://danbooru.donmai.us/posts/9337754 https://twitter.com/Szs0K/status/1898181831419465773	MV	© the artist (reference use only)
18	konachan:369558	see source	https://konachan.net/post/show/369558 https://www.pixiv.net/en/artworks/114878436	MV, SB05	© the original artist (reference use only)
19	wallhaven:jxg9rw	uploader MrPato	https://wallhaven.cc/w/jxg9rw –	MV, SB05	© the original artist (reference use only)
20	wallhaven:o5p9wl	uploader MrPato	https://wallhaven.cc/w/o5p9wl –	MV, SB05	© the original artist (reference use only)
21	commons:109860690 File:NDL-DC 1303208-Utagawa Hiroshige-名所江戸百景 永代橋佃しま-安政4-crd.jpg	Utagawa Hiroshige	https://commons.wikimedia.org/wiki/File:NDL-DC_1303208-Utagawa_Hiroshige-%E5%90%8D%E6%89%80%E6%B1%9F%E6%88%B8%E7%99%BE%E6%99%AF_%E6%B0%B8%E4%BB%A3%E6%A9%8B%E4%BD%83%E3%81%97%E3%81%BE-%E5%AE%89%E6%94%BF4-crd.jpg –	SB03	Public domain
22	commons:11159377 File:Hiroshige, The city flourishing, Tanabata festival, 1857.jpg	Utagawa Hiroshige	https://commons.wikimedia.org/wiki/File:Hiroshige,_The_city_flourishing,_Tanabata_festival,_1857.jpg –	SB03	Public domain
23	commons:67973284 File:Saruwaka-machi yoru no kei LCCN2008660961.tif	Ando, Hiroshige, 1797-1858, artist	https://commons.wikimedia.org/wiki/File:Saruwaka-machi_yoru_no_kei_LCCN2008660961.tif –	SB03	Public domain
24	commons:77567922 File:Utagawa Hiroshige - Fireworks at Ryogoku, from the series One Hun	Utagawa Hiroshige	https://commons.wikimedia.org/wiki/File:Utagawa_Hiroshige_-_Fireworks_at_Ry%C5%8Dgoku,_from_the_series_One_Hundred_Views_of_Famous_Places_in_-_1940.986_-_Cleveland_Museum_of_Art.tif –	SB03	CC0
25	commons:77597235 File:Utagawa Hiroshige - Eight Views of Kanazawa at Night - 1921.410 -	Utagawa Hiroshige	https://commons.wikimedia.org/wiki/File:Utagawa_Hiroshige_-_Eight_Views_of_Kanazawa_at_Night_-_1921.410_-_Cleveland_Museum_of_Art.tif –	SB03	CC0
26	danbooru:1613567 gradius / vic_viper	–	https://danbooru.donmai.us/posts/1613567 –	SB04	© the artist (reference use only)
27	danbooru:3997515 original	amenomori_howa	https://danbooru.donmai.us/posts/3997515 https://i.pximg.net/img-original/img/2020/07/12/21/40/27/82932648_p0.jpg	SB03	© the artist (reference use only)
28	danbooru:4467522 kimi_no_na_wa. / miyamizu_mitsuha	nengoro	https://danbooru.donmai.us/posts/4467522 https://i.pximg.net/img-original/img/2021/04/14/00/00/22/89135856_p0.png	SB02	© the artist (reference use only)

#	Work	Artist	Post page / original source	Used in	Licence
29	danbooru:4939355 original	ushiyama_ame	https://danbooru.donmai.us/posts/4939355 https://i.pximg.net/img-original/img/2019/07/07/19/18/18/75600953_p0.jpg	SB03	© the artist (reference use only)
30	danbooru:5243423 original	gemi	https://danbooru.donmai.us/posts/5243423 https://twitter.com/gemi333/status/1510187966706061316	SB03	© the artist (reference use only)
31	danbooru:5360153 original	shuu_illust	https://danbooru.donmai.us/posts/5360153 https://i.pximg.net/img-original/img/2022/05/18/00/00/02/98419493_p0.jpg	SB03	© the artist (reference use only)
32	danbooru:5493608 original	avogado6	https://danbooru.donmai.us/posts/5493608 https://twitter.com/avogado6/status/1439930817149501440	SB02	© the artist (reference use only)
33	danbooru:5555286 original	pasoputi	https://danbooru.donmai.us/posts/5555286 https://i.pximg.net/img-original/img/2019/09/15/00/00/05/76783413_p0.jpg	SB04	© the artist (reference use only)
34	danbooru:5559404 koimonogatari monogatari_(series) / kaiki_deishuu senjougahara_hitagi	watanabe_akio	https://danbooru.donmai.us/posts/5559404 https://ototoy.jp/_/default/p/877694	SB04	© the artist (reference use only)
35	danbooru:5584726 touhou / iizunamaru_megumu	fasnakegod	https://danbooru.donmai.us/posts/5584726 https://i.pximg.net/img-original/img/2022/08/13/00/57/32/100439997_p0.jpg	SB02	© the artist (reference use only)
36	danbooru:5752581 original	patch_oxxo	https://danbooru.donmai.us/posts/5752581 https://foundation.app/@patch_oxxo/memory-oxxo/2	SB03	© the artist (reference use only)
37	danbooru:6128091 macross macross:_do_you_remember_love? / hayase_misa	danmakuman	https://danbooru.donmai.us/posts/6128091 https://i.pximg.net/img-original/img/2023/03/04/06/25/21/105893886_p0.jpg	SB04	© the artist (reference use only)
38	danbooru:6195000 synthesizer_v utau / kasane_teto kasane_teto_(sv)	sakauchi_waka	https://danbooru.donmai.us/posts/6195000 https://piapro.jp/t/eU_0	SB01	© the artist (reference use only)
39	danbooru:6320205 synthesizer_v utau / kasane_teto kasane_teto_(sv)	sakauchi_waka	https://danbooru.donmai.us/posts/6320205 https://twitter.com/sakauchi0/status/1651481324274974721	SB01	© the artist (reference use only)
40	danbooru:6342898 hyouka / chitanda_eru oreki_houtarou	maburoku	https://danbooru.donmai.us/posts/6342898 https://i.pximg.net/img-original/img/2021/12/11/12/43/19/94703640_p0.png	SB03	© the artist (reference use only)
41	danbooru:6640306 eshi_100_nin_ten original	hiten_(hitenkei)	https://danbooru.donmai.us/posts/6640306 https://files.yande.re/image/67f2872ad22da29219b6b373649d7df4/yande.re%201113987.png	SB03	© the artist (reference use only)
42	danbooru:7293124 honkai:_star_rail honkai_(series) / firefly_(honkai:_star_rail) stelle	nid417	https://danbooru.donmai.us/posts/7293124 https://i.pximg.net/img-original/img/2024/03/05/00/00/28/116629910_p0.png	SB02	© the artist (reference use only)
43	danbooru:7811285 animage kidou_keisatsu_patlabor / izumi_noa kanuka_clancy	suzuki_shunji	https://danbooru.donmai.us/posts/7811285 https://animarchive.tumblr.com/post/625721073437212672	SB04	© the artist (reference use only)
44	danbooru:7823803 original	chilfa_112	https://danbooru.donmai.us/posts/7823803 https://twitter.com/Chilfa_112/status/1809874816452685949	SB03	© the artist (reference use only)
45	danbooru:8017617 synthesizer_v utau / kasane_teto kasane_teto_(sv)	sakauchi_waka	https://danbooru.donmai.us/posts/8017617 https://www.instagram.com/p/CriSGEtPB_I/	SB01	© the artist (reference use only)
46	danbooru:8291941 synthesizer_v utau / kasane_teto kasane_teto_(sv)	sakauchi_waka	https://danbooru.donmai.us/posts/8291941 https://twitter.com/noreiyagi/status/1845717533636374708	SB01	© the artist (reference use only)
47	danbooru:8331004 synthesizer_v utau / kasane_teto kasane_teto_(sv)	sakauchi_waka	https://danbooru.donmai.us/posts/8331004 https://twitter.com/MaddyTheHuman50/status/1845591013420945765	SB01	© the artist (reference use only)
48	danbooru:857034 mother_(series) mother_2	seo_tatsuya	https://danbooru.donmai.us/posts/857034 https://i.pximg.net/img-original/img/2011/02/20/00/25/54/16810195_p0.jpg	SB02	© the artist (reference use only)
49	danbooru:8729395 original	gagagank0810	https://danbooru.donmai.us/posts/8729395 https://twitter.com/gagagank0810/status/1880270435440586859	SB04	© the artist (reference use only)
50	danbooru:9602269 utau voicepeak / kasane_teto kasane_teto_(voicepeak)	sakauchi_waka	https://danbooru.donmai.us/posts/9602269 https://sakauchi.fanbox.cc/posts/9749703	SB01	© the artist (reference use only)
51	wallhaven:13mrg3	uploader Rocketizada	https://wallhaven.cc/w/13mrg3 –	SB02	© the original artist (reference use only)

#	Work	Artist	Post page / original source	Used in	Licence
52	wallhaven:2kydq9	uploader Deireadh	https://wallhaven.cc/w/2kydq9 –	SB02	© the original artist (reference use only)
53	wallhaven:85852j	uploader JustJon	https://wallhaven.cc/w/85852j –	SB02	© the original artist (reference use only)
54	wallhaven:gp17ve	uploader TankerNejla	https://wallhaven.cc/w/gp17ve –	SB03	© the original artist (reference use only)
55	wallhaven:rdlypj	uploader fakenews	https://wallhaven.cc/w/rdlypj –	SB02	© the original artist (reference use only)
56	wallhaven:wy6vqx	uploader iamctz	https://wallhaven.cc/w/wy6vqx https://www.pixiv.net/member_illust.php?mode=medium&illust_id=74510189	SB02	© the original artist (reference use only)
57	wallhaven:x6yrez	uploader Cyb3rCr0w	https://wallhaven.cc/w/x6yrez –	SB02	© the original artist (reference use only)
58	wallhaven:x8zyqo	uploader muskratracer	https://wallhaven.cc/w/x8zyqo https://www.pixiv.net/en/artworks/90351903	SB02	© the original artist (reference use only)

Like a Prism (P1) frames (Fig. 11):

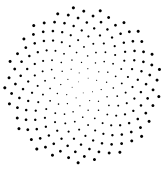
- The Hatsune Miku illustrations are official Crypton Future Media artwork distributed through piapro, used under CC BY-NC 3.0 (https://piapro.net/intl/en_for_creators.html).
- The P1 project files record the licence but not per-image URLs.
- The male-vocal figure is a photograph supplied by the artist.

D.2 Reference music videos

The seven MVs in Fig. 16 were studied for timing statistics only; the table after Fig. 16 links each one.

D.3 Software, data sources and fonts

- Hermes Agent: https://hermes-agent.nousresearch.com/docs; pricing: https://docs.claude.com/en/docs/about-claude/pricing
- Demucs https://github.com/facebookresearch/demucs; Beat This! https://github.com/CPJKU/beat_this; ADTOF https://github.com/MZehren/ADTOF
- faster-whisper https://github.com/SYSTRAN/faster-whisper; Whisper https://github.com/openai/whisper; torchcrepe https://github.com/maxrmorrison/torchcrepe; torchaudio (MMS forced aligner) https://pytorch.org/audio
- PixiJS https://pixijs.com; skia-python https://github.com/kyamagu/skia-python; FFmpeg https://ffmpeg.org; Real-ESRGAN https://github.com/xinntao/Real-ESRGAN; rembg https://github.com/danielgatis/rembg; matplotlib https://matplotlib.org
- KanjiVG stroke data, CC BY-SA 3.0, https://kanjivg.tagaini.net
- Art sources: Danbooru https://danbooru.donmai.us, wallhaven https://wallhaven.cc, Konachan https://konachan.net
- Fonts, SIL Open Font License 1.1: Shippori Mincho B1, Zen Kaku Gothic New, Dela Gothic One, Bodoni Moda, Martian Mono, Shantell Sans, Kalam (https://github.com/google/fonts); GenEi Antique (源暎アンチック, OFL text distributed with the font)



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