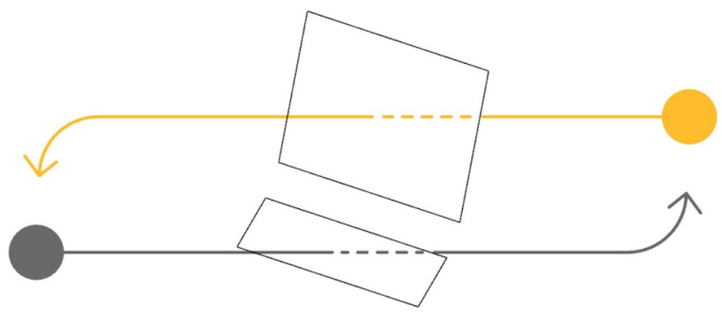
Human/AI Collaborative Control

interaction patterns



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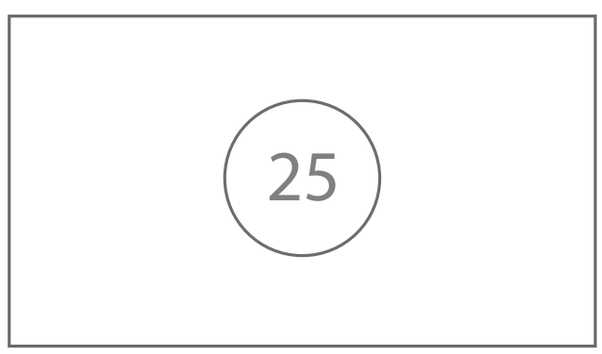
System Level Patterns

DECOUPLED SCREEN

The goal of screen decoupling is to provide the ability to control the vehicle with the curved screen while maintaining one's gaze on the road ahead. This allows the user to simultaneously supervise their environment and observe feedback from the vehicle as it appears on the secondary screen.

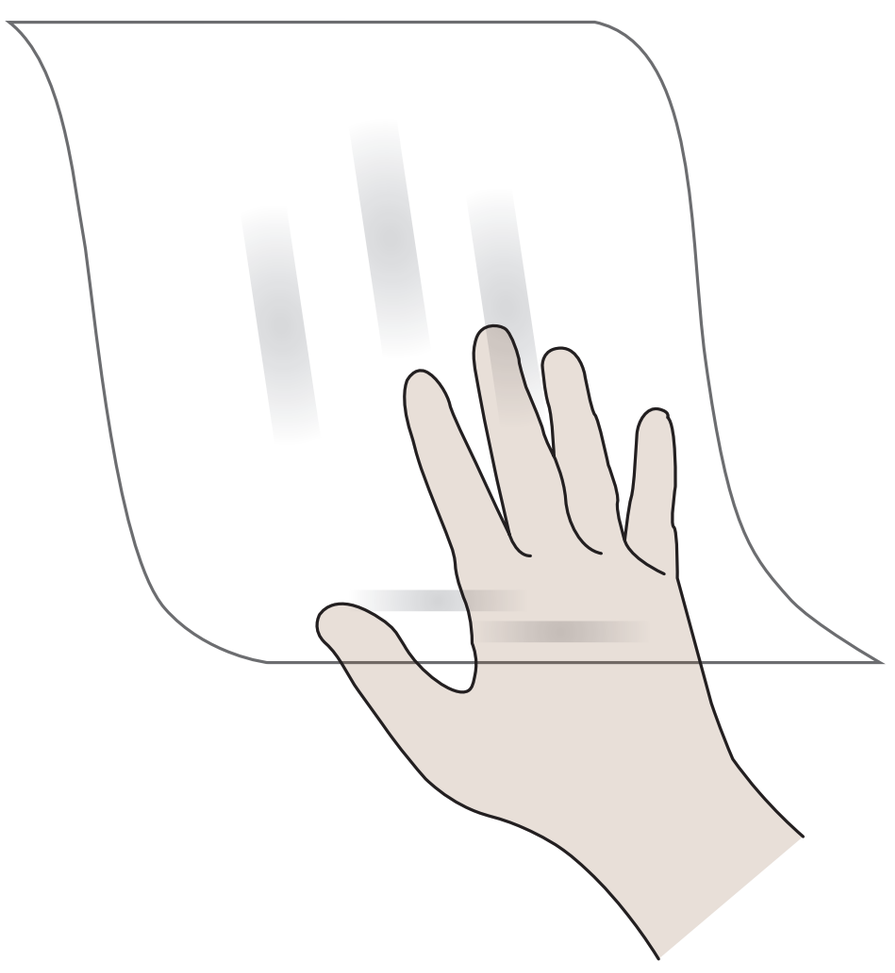
SECONDARY SCREEN // AI FEEDBACK

The vehicle AI provides feedback to the user that commands have been received and are being executed. Additionally, it prompts the user to make decisions.



CURVED SCREEN // HUMAN INPUT

The driver interacts with the curved screen during semi-autonomous driving. This enables them to provide input for changes in speed, lateral positioning within a lane, and go-or-don't-go decisions.



FILL TO TARGET PATTERN

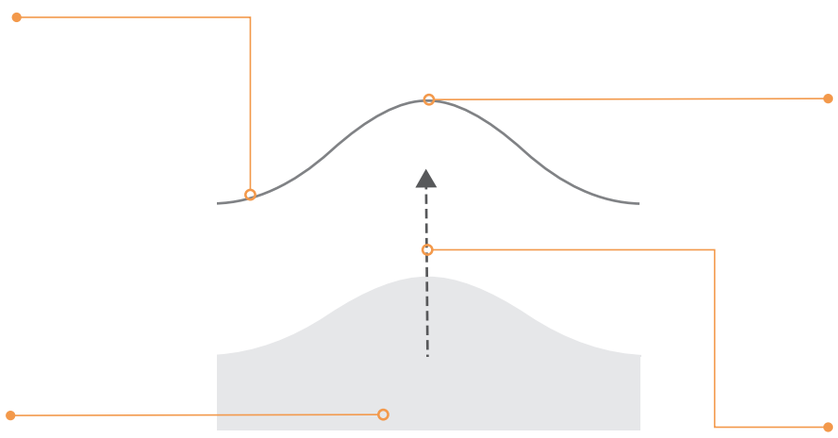
As actions are initiated by the driver,, achieving the desired state may take time. Increases in speed and other driving maneuvers typically cannot be accomplished instantaneously. As such, the secondary monitor confirms the users input then shows the vehicles progress towards that command.

TARGET LINE

The user's interaction expresses an intent or a quantity, which is represented by this line. The vehicle then progresses towards this intent or quantity if deemed safe, with progress represented by the fill approaching the line.

PROGRESS FILL

As the vehicle realizes a proposed change, the fill moves gradually to the target line as the action is completed.



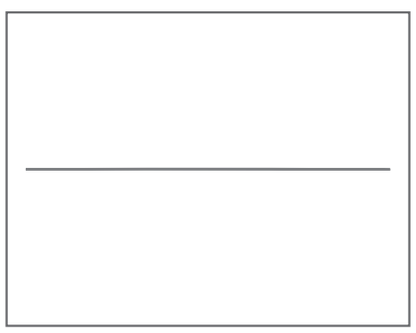
TRACKING WITH HAND

For controls effecting continuous values, horizontal or vertical movement of the target line tracks with the users hand movements on the curved screen.

PROGRESS TO TARGET

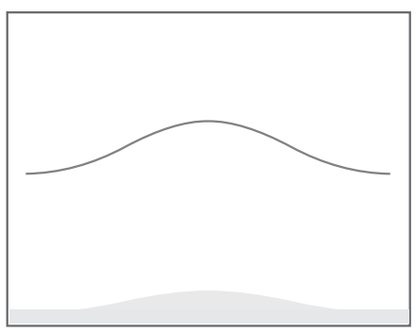
As progress towards the target is achieved, the progress fill "grows" toward the target line.

STEP BY STEP As the user interacts with the curved control, the secondary screen progress from its resting state, to setting a target, and finally illustrates progress towards that target.



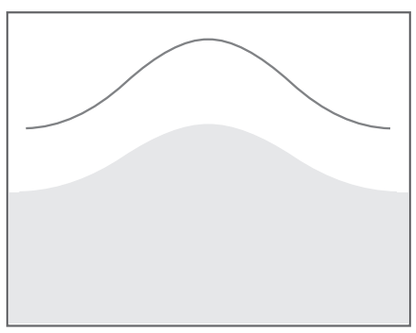
RESTING STATE

The fill-to-target pattern is prefaced by a straight line element, which transforms into the curved shape of the target line when an action is initiated by the user.



ACTION INITIATED

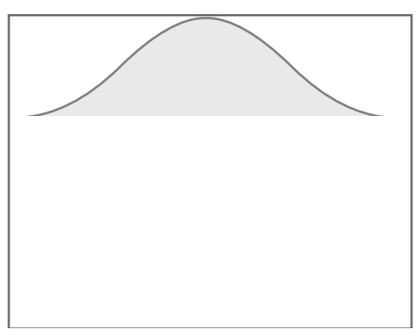
The target line and progress fill appear on the monitor once an action is initiated, with the target line representing the presently set target mapped to hand movement, and the progress fill showing current vehicle progress toward this target goal.



ACTION IN-PROGRESS

As the action is executed, the progress fill moves towards the target line.

If target is non-binary, the height of the target line on the screen corresponds with the magnitude of the change.



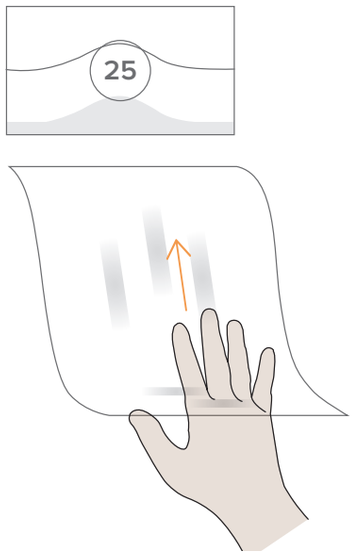
ACTION COMPLETED

Once the progress fill reaches the target line, the secondary monitor presents a confirmation of completion to the user.

The vehicle has fully realized the user's command.

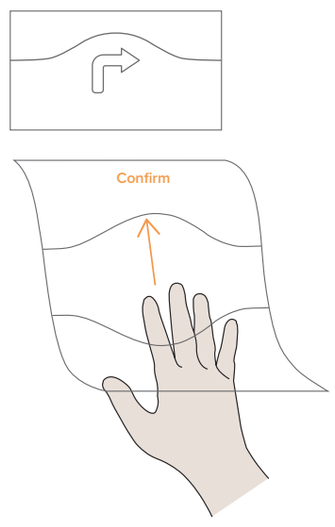
DIRECTIONAL CONSISTENCY

A central principle of the design is that pushing forward and up maps to forward progress of the vehicle, be that speed or confirming a decision that tells the vehicle to advance in a certain manner.



SPEED UP

To increase speed, the user moves their hand up the control, resulting in immediate speed increase once the movement threshold is reached.

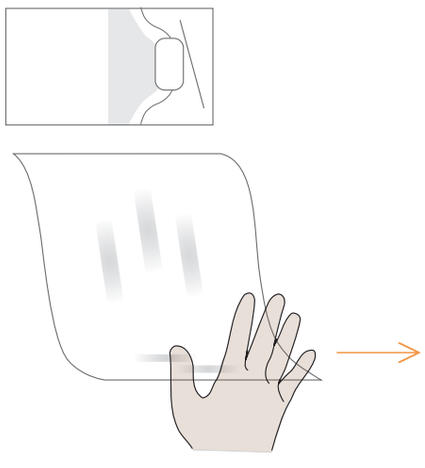


BINARY DECISION

To confirm a binary decision, the user moves their hand up the control. Once they achieve a certain distance/ height, their decision is confirmed and the car movement is initiated.

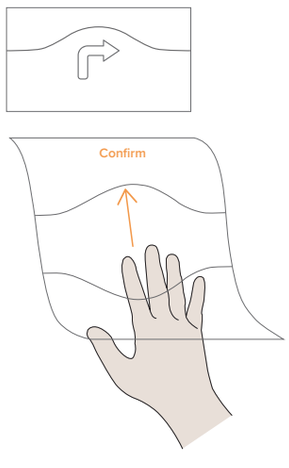
INTENTIONALITY: SWIPES OVER TAPS

All actions initiated through the control require swipe movements instead of taps. This is to minimize the actions that are initiated by accident and to avoid confusion over whether certain elements on the screen can be tapped - a common source of error; nothing in the interface can be tapped.



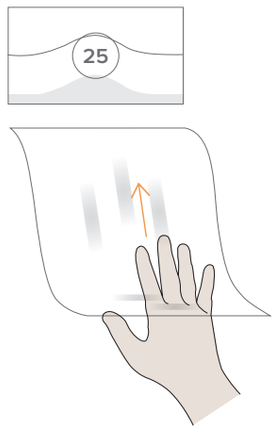
LANE ADJUST

Swipe right to move right.



BINARY DECISION

Push up to Al Space to Confirm.



SPEED ADJUST

Push upwards to increase speed.

1 Feature #1 **Speed Adjustment**

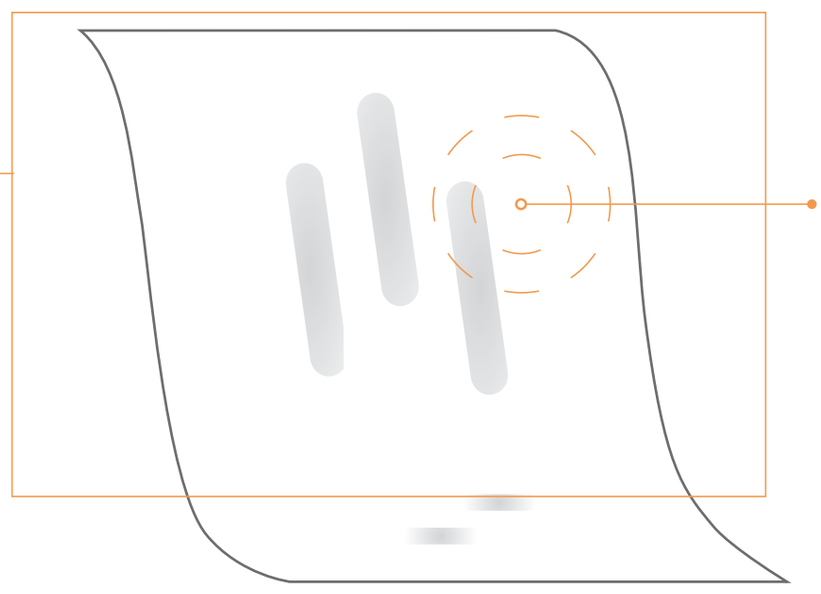
INTERACTION AREA

Speed adjustment is accessible from the primary screen, above the in-lane adjustment area. It is available at all time while driving except when a binary prompt appears. Users can swipe vertically anywhere on the speed adjustment area to communicate their desire to increase or decrease speed.

SPEED CONTROL AREA

The user moves their hand/fingers up or down in this area to increase or decrease speed, respectively.

Feedback as to what speed users are setting appears on the secondary screen above the control.



MOVEMENT THRESHOLD

There is a degree of movement required before the system will register that an action is being performed on behalf of the user.

This movement threshold exists to avoid false positives, i.e. from touching the control by accident.

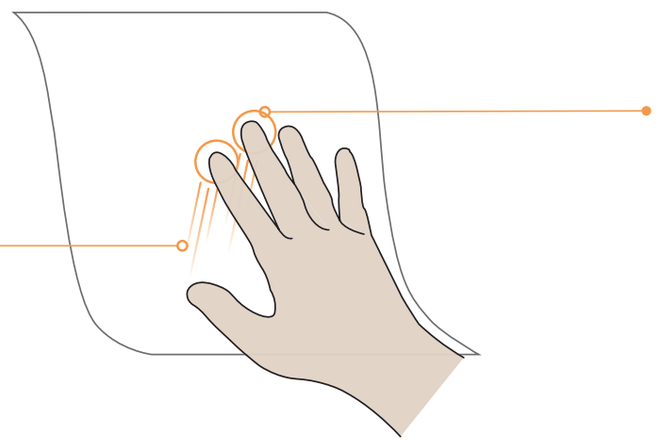
TOUCH FEEDBACK

As the user touches the curved screen, visual feedback is presented on the control to indicate that movement is being perceived. This feedback entails circles around points of contact (like finger tips), and trails as the hand moves across the surface.

TRAIL

The trail left behind points of contact with the control visually represents the magnitude and speed of swipes.

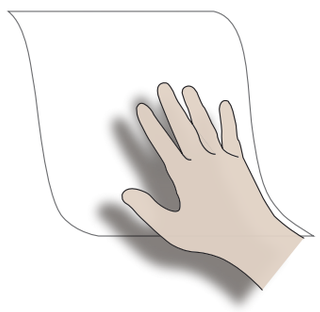
The faster one swipes, the longer the trail is present. The length of the trail thus corresponds acts as an indication of the increased effect on the rate of acceleration (due to faster swiping)



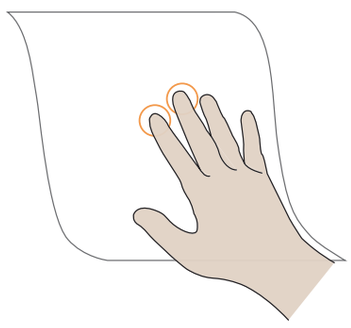
TOUCH CURSOR

Circles appear on the control around points of contact, demonstrating the system is live and registering input from the user.

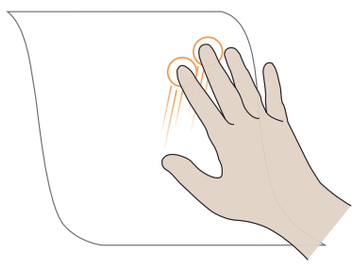
STEP BY STEP As the user touches the control, circles appear around the points of contact. As the user's hand moves across the surface, the trail behind these circles indicates the speed and magnitude of swipes.



Nothing appears on the control before hand contact.



As the user's hand makes contact with the control, circles appear around points of contact (fingertips).



As the user moves their fingers, a trail briefly appears at the previous location of the user's fingers.

NOTE: Trail and touch cursor also seen in lane adjustment area.

SECOND SCREEN FEEDBACK

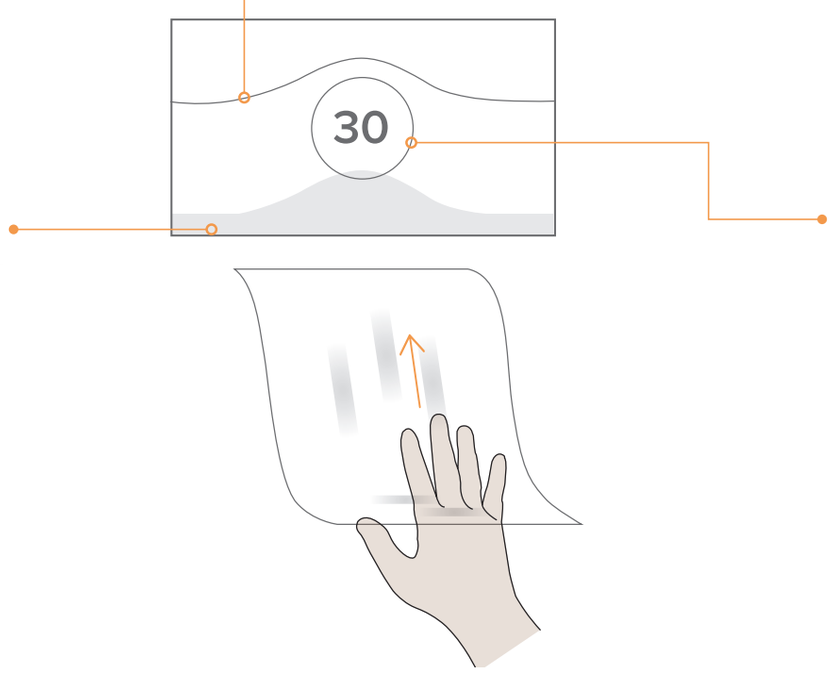
As actions are initiated by the driver, the AI of the vehicle needs time to confirm that conditions are appropriate for that action. In addition, achieving the desired state may take time. For instance, the vehicle requires time for a smooth transition from 25 mph to 40 mpg. The secondary screen provides feedback to the user about the target speed they are setting and when they will reach their desired speed.

SPEED TARGET

Target line moves up or down depending on the direction of hand movements, setting a new target speed.

SPEED PROGRESS

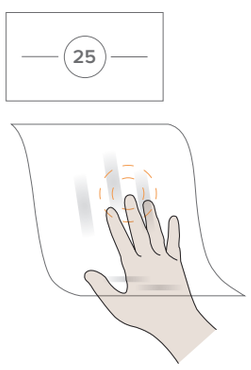
As the vehicle realizes the proposed speed, the fill moves gradually to the target line.



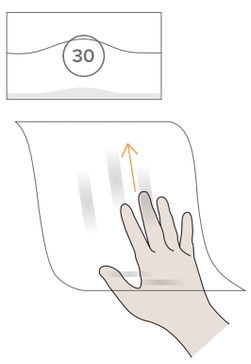
CURRENT/NEW SPEED

The number in the center of the secondary screen represents current speed, until the user pushes upwards/downwards, when it then changes in value and represents the new target speed.

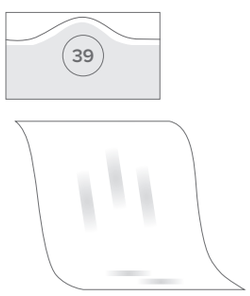
STEP BY STEP As the user interacts with the curved control, the secondary screen progresses from its resting state, to setting a target, to finally reaching the desired speed. The target line tracks with the user's hand motion.



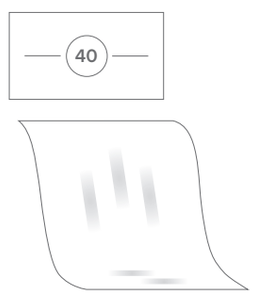
The user places their hand on the control, and stays in the movement threshold. The secondary screen shows the current speed.



The user moves their hand up the control. The target line and progress fill appear. The center number represents the target speed.



As the car increases speed towards 40 mph, the progress fill continues to move towards the target line.



The target speed is achieved by the vehicle, the fill reaches the line, and the visual briefly returns to the previous state of displaying current speed.

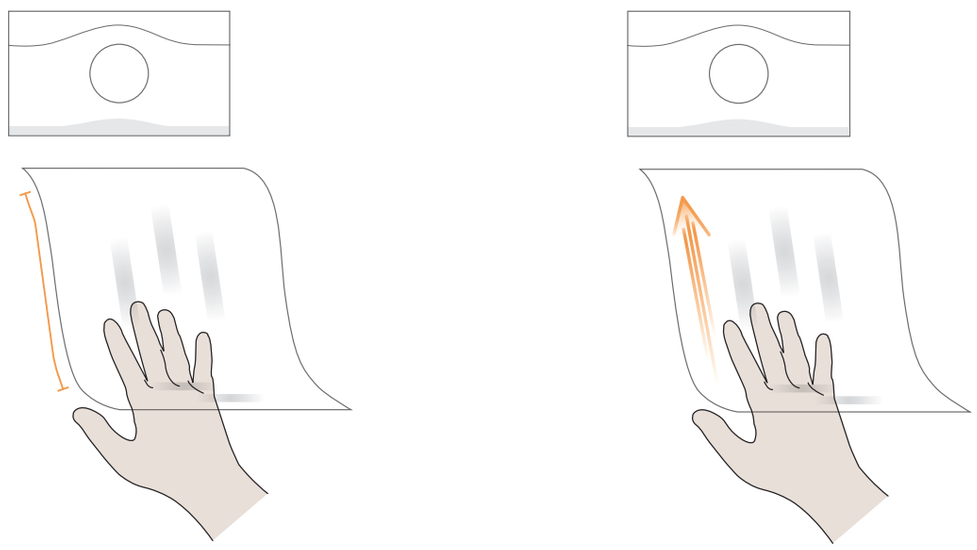
MAGNITUDE & ACCELERATION CONTROL

The magnitude of a speed increase is based on two factors: the travel distance of one's hand on the screen and the movement speed at which one's hand moves.

The maximum increase/decease allowed is a percentage change from the current speed. For example. If the manufacturer sets the max change value to 30%, a driver traveling at 50mph can increase to 65mph or decrease to 35mph with a single interaction.

A max change can be achieved by moving the hand roughly the full length of the speed control area, or by moving it very quickly over less distance.

Last, the speed at which the user swipes has some effect on the rate of acceleration, but acceleration should remain smooth and never jarring to the driver or passenger.



TRAVEL DISTANCE

As the user moves their hand the target speed further approaches the min or max change.

MOVEMENT SPEED

The movement speed of a gesture effects the amount of the increase/decrease, and to a lesser extend the rate of change.

2

Feature #2 **Lane Adjustment**

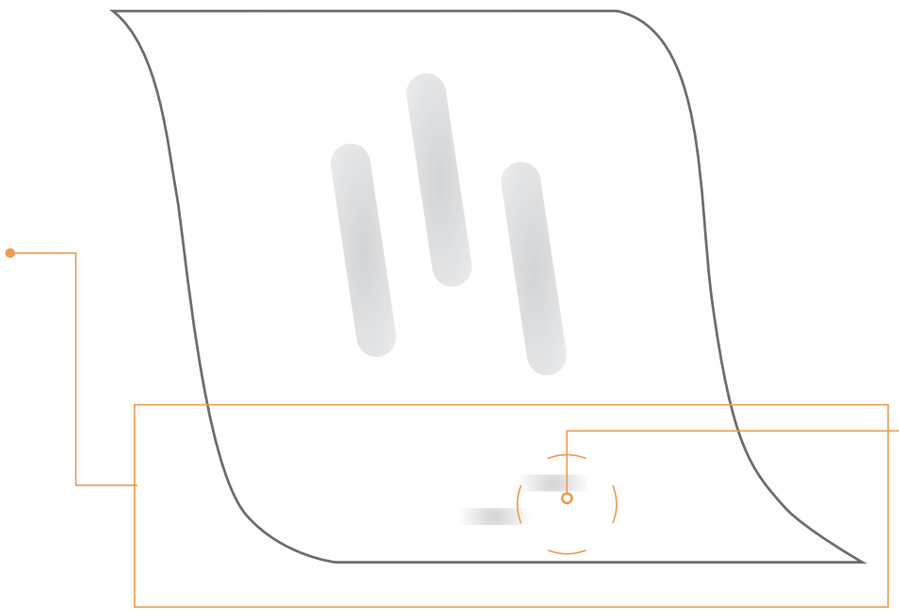
INTERACTION AREA

*The lane adjustment area of the control is across the lower portion of the primary display. The user can move their fingers left or right to shift the car's position **within** a lane.*

Discomfort regarding position in a lane, and position in relation to other objects and vehicles, is one of the primary causes of discomfort while in a semi-autonomous vehilce.

LANE CONTROL AREA

Sideways movements in this area result in ajustments within a lane to the left or right, depending on the direction of hand movement.



MOVEMENT THRESHOLD

There is a degree of movement required before the system will register that an action is being performed on behalf of the user.

This movement threshold exists to avoid false positives, i.e. from touching the control by accident.

SECONDARY SCREEN FEEDBACK

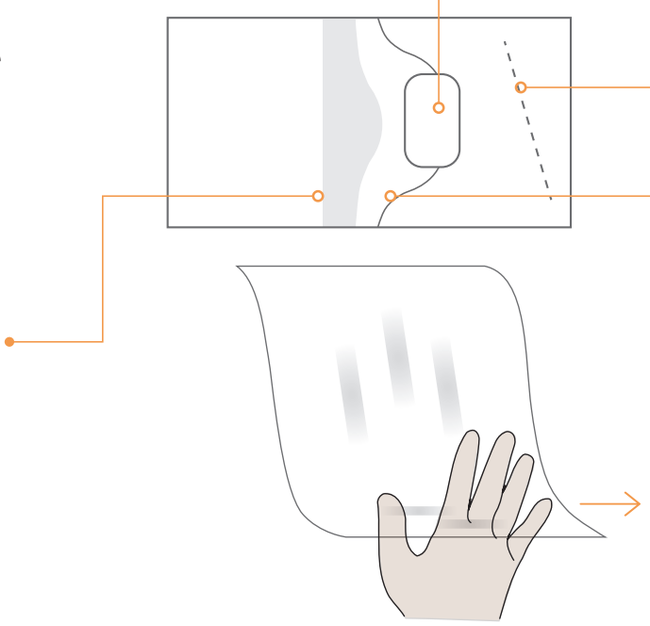
In lane adjustment, the secondary screen communicates the degree of shift a user's hand movements have input. It also provides feedback that the requested lane adjustment is underway, as the vehicle may delay execution of the command depending on its surroundings.

VEHICLE ICON

The vehicle is represented by an abstracted car outline on the screen that moves toward the direction of shift, representing the target lane position.

MOVEMENT PROGRESS

As the vehicle moves in the proposed direction, the fill moves gradually to reach the target location, leveraging the same fill-to-target pattern used by the secondary monitor display for speed.



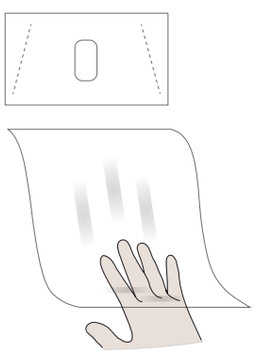
LANE LIMIT

The dashed line on either side of the screen represents the lane line one is moving towards. The lane changes from solid to bold when the user has reached the position limit on that side.

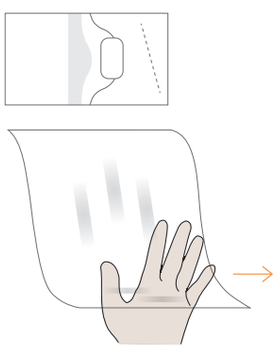
MOVEMENT TARGET

The movement target represents position in the lane requested by the user, towards which the vehicle begins moving.

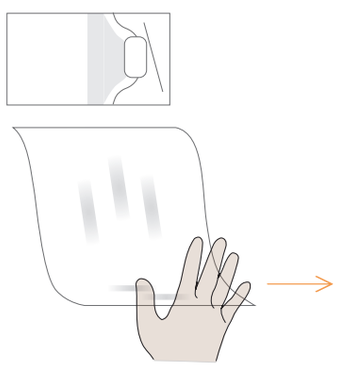
STEP BY STEP As the user moves their hand to the side in the lane adjustment portion of the control, the secondary monitor shows the new target position as well as progress toward achieving that position. If the user's gesture reaches the limit for a safe maneuver, the screen displays a bolded lane line.



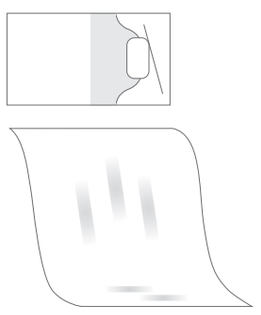
If the user is in the readying position, car position in the lane appears on the secondary screen.



As the user moves right in the lane position portion of the control, the screen shows the target location being indicated by the degree of hand movement.



If the user continues to move right, they reach the right-most limit, based upon the surrounding context. The screen shows a solid, bolded lane line.



After the user lets go of the control, the car reaches the position indicated on the screen, with the progress fill reaching the movement target line and car.

2 Feature #3 **Binary Decisions**

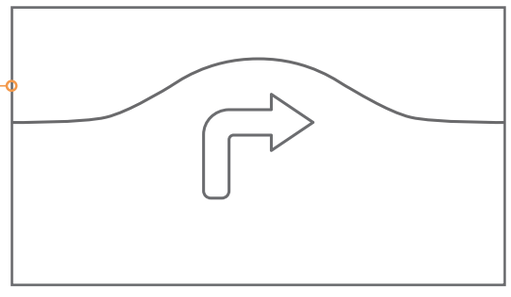
INTERACTION AREA

During semi-autonomous driving, the vehicle may offer the driver the option to make a go or don't go (binary) decision. A prompt will appear on the secondary screen, and the primary display will present the two options while hiding the speed and lane control.

The user responds to binary prompts by moving up or down on the control. Sliding the confirmation slider to the secondary screen / AI space confirms the decision. Swiping the dismiss slider down off of the screen dismisses the prompt.

DECISIONS PROMPT

When a binary prompt becomes available, it will appear on the secondary screen, and the curved display will change to the two options available for the contextual decision.



CONFIRMATION SLIDER

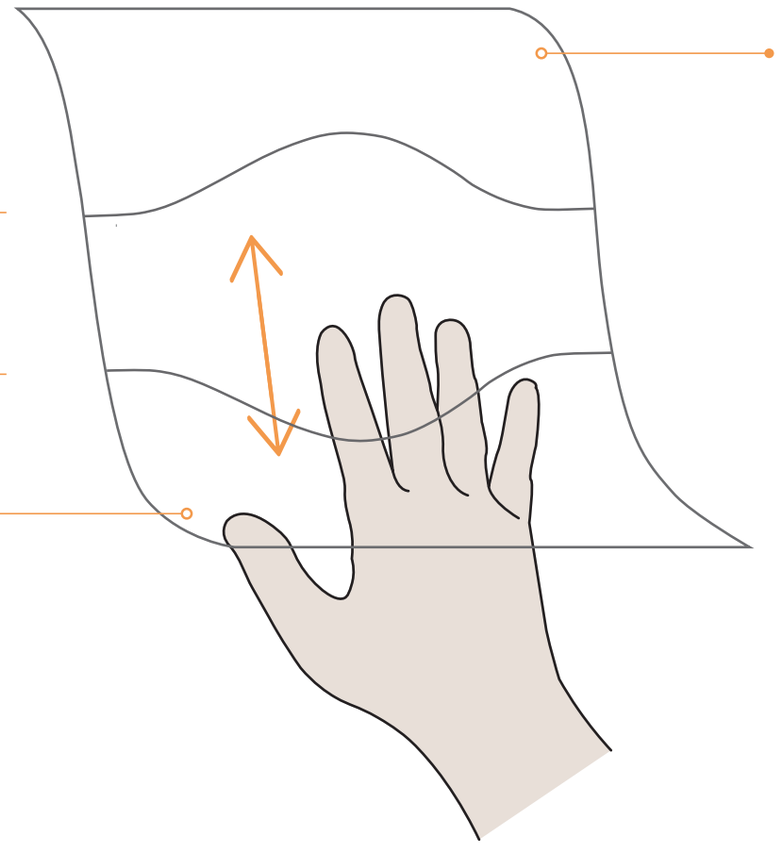
Based upon the prompt provided, the confirmation of that option will appear in the upper portion of the curved control. The user can make this choice by moving their hand up the control.

ACTIVE CONTROL AREA

The user moves their hand up or down starting from this area to pass the movement threshold required to register a decision.

DISMISSAL SLIDER

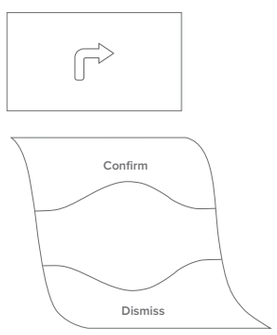
Regardless of the prompt, there will always be a dismiss option that can be initiated by the user moving their hand down the curved surface.



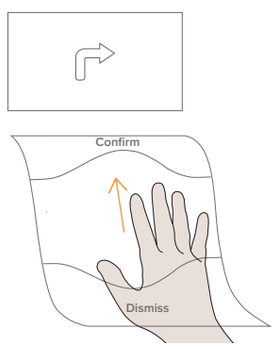
PROMPT AND FEEDBACK

When binary decisions become available, the secondary screen prompts the user. The user can either confirm or dismiss a decision. Upon confirmation, the secondary screen displays the progress towards completing that action.

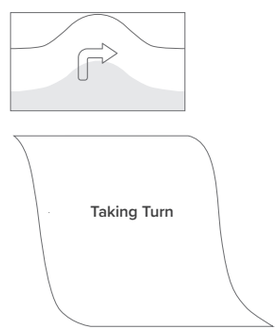
STEP BY STEP Once the user pushes either the confirmation or dismissal slider off of their respective edges of the curved screen (top and bottom), the secondary screen begins an animation. The animation communicates that the command has been received and shows the progress of the vehicles actions.



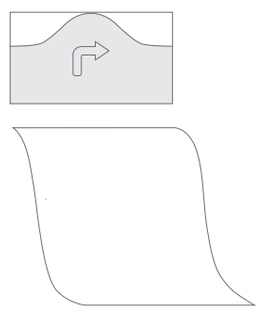
A prompt appears, informing the user that an action is available. The primary screen changes from speed and lane adjustment to showing confirm and dismiss options.



The user swipes on the middle portion of the screen to push the confirm or deny sliders up or down, respectively. The user selects a action by pushing that slider past the edge of the screen.



Once an option is selected, the second screen shows the vehicle's progress in executing the action.



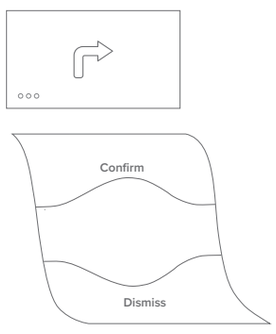
Once the action has been completed, the fill meets the target line and the primary screen changes back to displaying speed and lane adjustment shortly after.

DECISION TIMEOUT

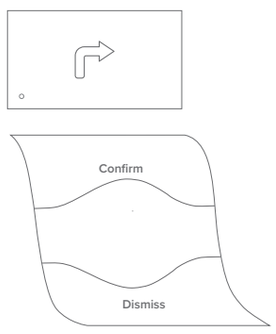
All binary decisions prompts expire after a period. There are two distinct methods for determining the length of time a user has to make a decision: In cases where the window of opportunity is based on traffic dynamics, such as merging into a lane when vehicles are approaching, timeout is determined by car's understanding of the window of time for safe execution.

When it does not appear that traffic dynamics will preclude future actions, prompts expire after a predetermined amount of time.

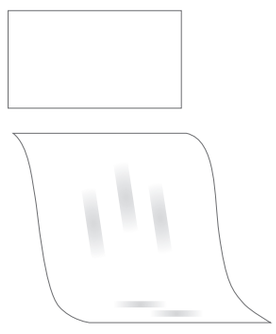
STEP BY STEP A simple indicator of zero, one, two, or three dots represents to the user how much time is remaining for them to make a decision. As to not distract the user, dots simply disappear; animations are not used.



When a prompt appears on the secondary screen three dots appear, loosely indicating the amount of time the remains to commit to an action.



As time progresses, dots disappear, indicated decreased time remaining to make a decision.



Once the final dot disappears, the prompt disappears from the secondary screen, and the primary screen returns to speed and lane adjustment.